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INSTRUMENTS

INDUSTRIAL — SCIENTIFIC

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voted to Measurement and Control Problems

3. No. 1 Pittsburgh, Pa. January, 1930

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- A High Pressure Meter
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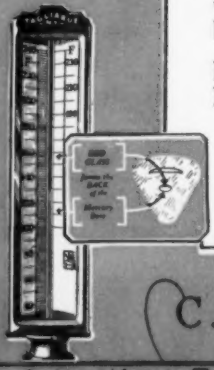

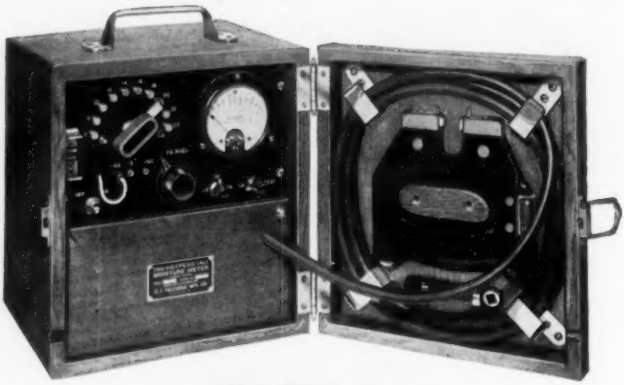

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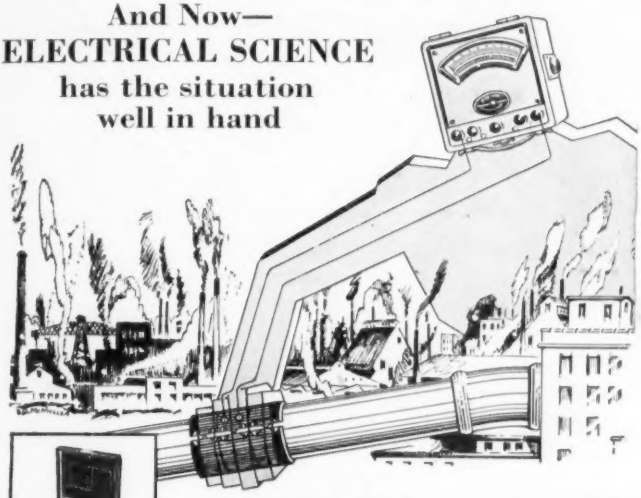
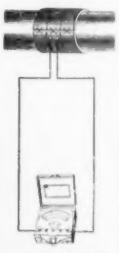


The Instrument



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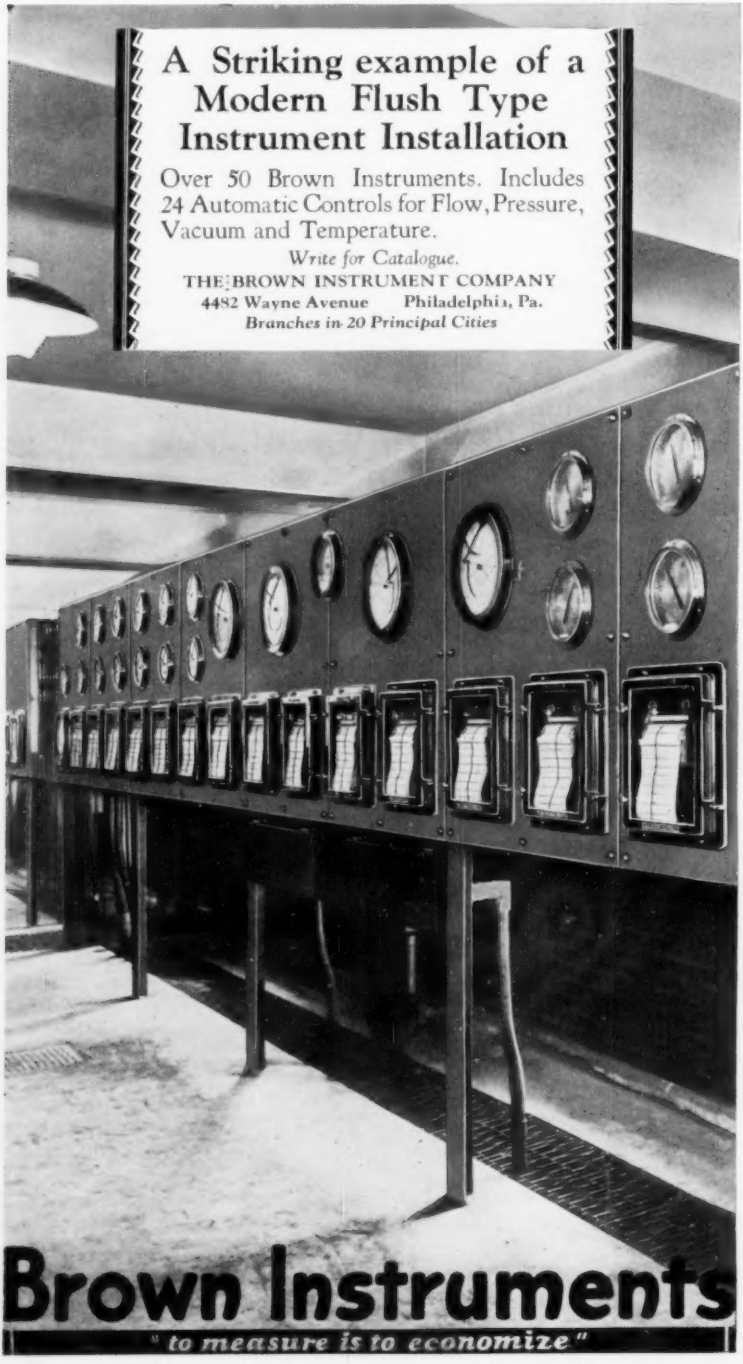
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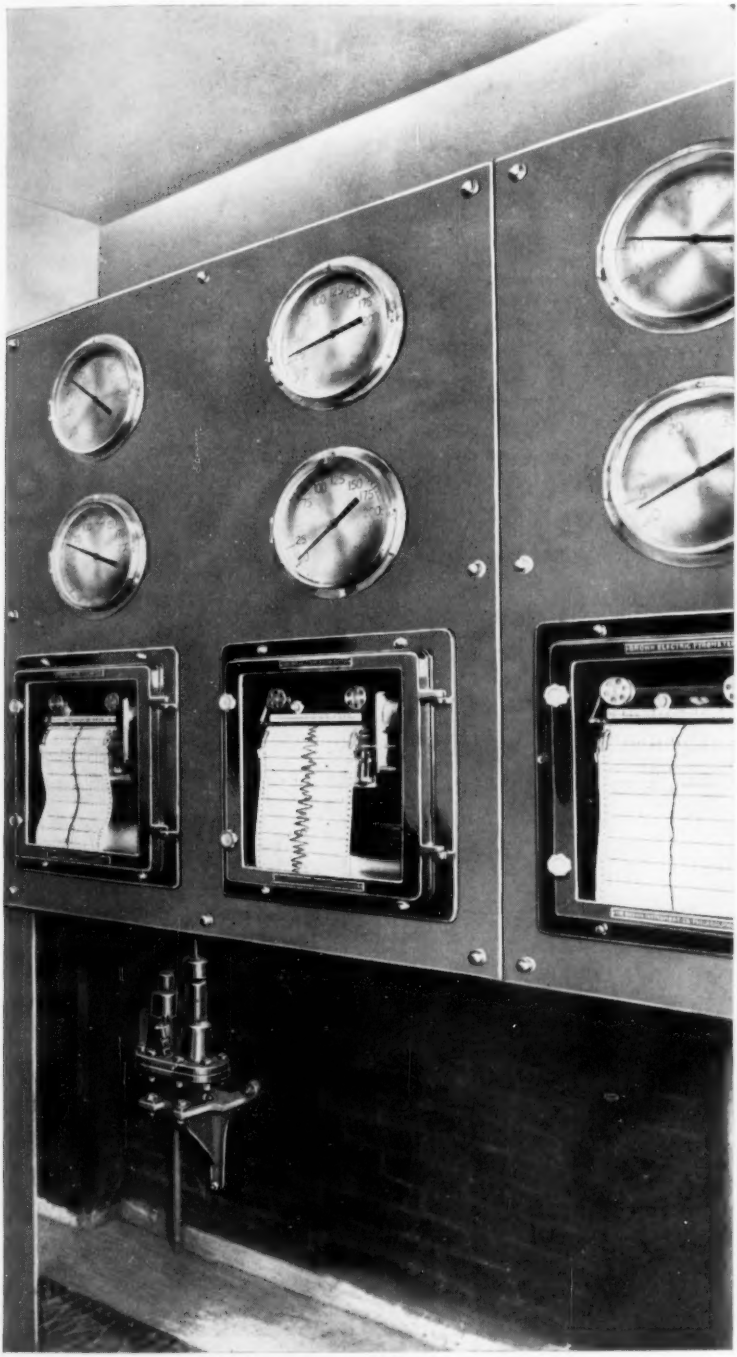

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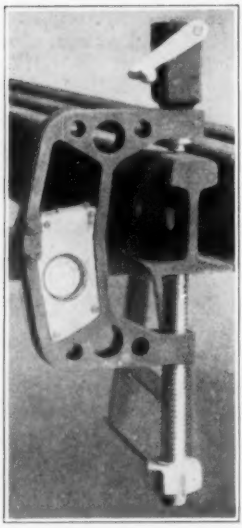

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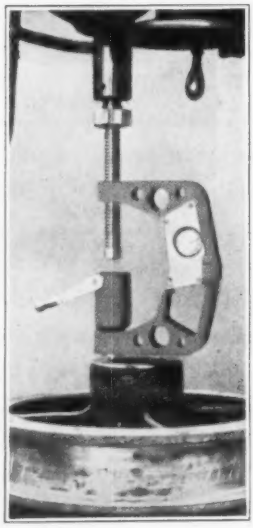

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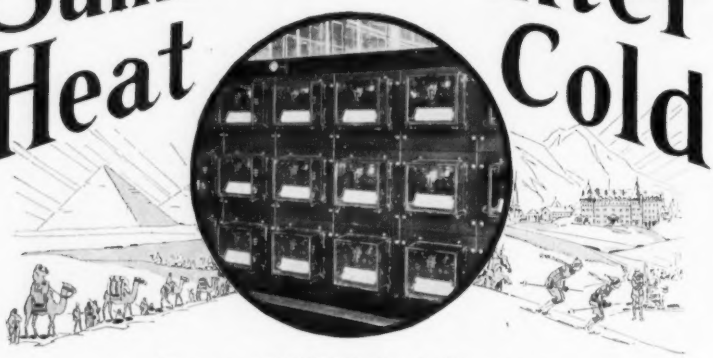

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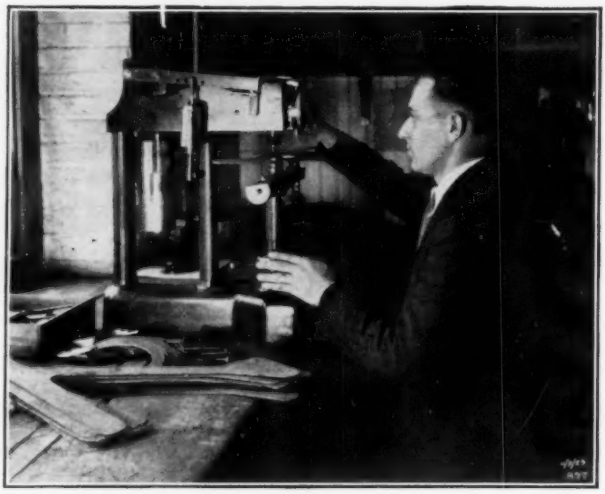

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INDUSTRIAL — SCIENTIFIC

(Reg. U. S. Pat. Off.)

Vol. 3, No. 1 JANUARY, 1930 Pittsburgh, Pa.

To Our Readers

WITH the December issue, INSTRUMENTS completed two years of publication. With the rapid development of the industrial measuring science, there is a decided need for a publication to continually point out the developments, which have been made. INSTRUMENTS from the beginning made every effort to serve its readers, making information on instruments and devices for measurement, testing and control available.

Every effort will be made during the coming year to extend this service. Beginning in the October issue of INSTRUMENTS the first installment of the translation of the latest German book on this subject appeared. Beginning with this issue, the first installment of a series entitled "The Engineers' Handbook of Industrial Instruments" appears.

Also beginning with the February issue, the Current Literature Abstracts will be classified as is explained in more detail below.

In this issue will be found the indexes of the articles and authors appearing in INSTRUMENTS during the first two years of publication.

A new reader service begins with this month. This service will appear under the caption "INSTRUMENTS Book-of-the-month." Engineers should add a number of books on measurements to their library. We believe a small investment at regular intervals for the outstanding books covering this field will be very profitable. Therefore each month the editorial staff will designate a book, which it believes will be a valuable addition to your library.

INSTRUMENTS will be bigger and better in 1930. Send in your subscription immediately.

The Engineers' Handbook of Industrial Instruments

IN this issue appears the first installment of a series of articles on industrial instruments entitled "The Engineer's Handbook of Industrial Instruments." There is a very decided need for a book of this character due to the rapid development of the industrial measuring science.

Instruments for the supervision and control of industrial processes are still not used to the extent they should be. These devices are not considered as absolutely essential, "because the plant can run without them."

What economies can be accomplished, though, by systematic supervision of any process, can only be shown after they have been installed. An installation, though, should by all means be complete in every respect, for example, in a boiler plant a feed water meter should not be installed without also providing for the measurement of the fuel used, as a determination of the boiler efficiency is only possible by measuring the water converted to steam and the fuel used to accomplish this. Without instruments it is not possible to discover where losses occur and how these can be avoided.

The author of this series is excellently fitted by training and experience to make this book of exceptional value to engineers, production executives and other interested in measurement, inspection and control. The impartiality of the author, who is not in the employ of any one manufacturer, is beyond question. If there is any partiality it is only a natural leaning toward American instruments and the obvious difficulties of assembling and digesting information on foreign instruments. The series will be authoritative appearing under the auspices of INSTRUMENTS, a magazine serving the needs of all industries through promoting a greater knowledge of all meritorious instruments, and also due to the assistance of the manufacturers, constituting the instrument making industry, who had the opportunity of contributing illustrations and other forms of editorial assistance.

Current Literature Classified

BEGINNING with the February issue the abstracts, of articles on measurements and instruments appearing in a large number of domestic and foreign publications, will be classified. During the years 1928 and 1929 —periodicals were watched for information of interest to the instrument user and manufacturer. This improvement is in line with our effort to serve our readers. As INSTRUMENTS is published and edited for busy readers the references on instruments and devices for measurement, testing and control can be looked over in a few minutes.

Recent Readers' Comments

Dr. C. A. Heiland, Professor in Charge, Department of Geophysics, Colorado School of Mines.

"Please enter my subscription for your journal, "Instruments" for two years, beginning with October 1929 issue, for which bill me for $3.00."

I believe that the establishment of such a journal especially with reference to scientific instruments fills a long felt want in this country."

James Dowd, Chief Electrician, M. W. Kellogg Co.

"Enclosed are a number of pages cut from your publication, which I have neglected to send in until now. As they are many in number and cover a very wide range in the instrument line, I feel that some explanation is necessary.

Since we are continually experimenting and building pipe stills and cracking plants, we naturally have use for a number of various instruments. Since all types of instruments come under my department, we are not confined to electrical alone, but to all of these that I have marked on the pages cut from your publication."

Industrial Temperature Instrument Developments in 1929

M. F. Béhar*

IT affords keen delight to watch how a principle utilizable at first only in delicate laboratory instruments finds its way to the plant. Thus surveying what a closing year has brought forth in the way of new or improved industrial temperature instruments amounts to seeing an accelerated motion picture; and while the scenario of "1929" showed no dramatic climax (no revolutionary development), the observer was nevertheless thrilled at striking evidences of earnest efforts to increase sensitivity without sacrificing ruggedness, to augment durability without impairing accuracy of measurement or regulation.

Yes, the scientific instrument of today is the industrial instrument of tomorrow, but to declare offhand that a typical industrial instrument is "less accurate" than a typical scientific instrument designed to measure the same class and order of variable magnitudes (or to control the same condition) becomes an increasingly false generalization as each year adds a rich harvest of the fruits of the instrument makers' labors.

I. INDICATING

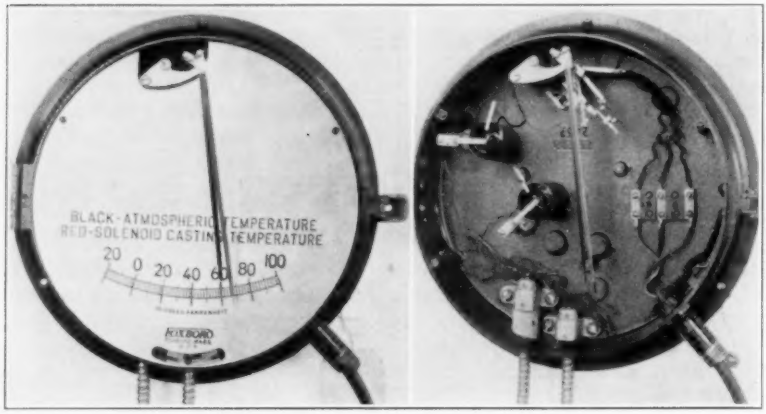
1. INDUSTRIAL THERMOMETERS—We naturally start with the simplest and oldest industrial temperature instruments, the liquid-in-glass thermometers. In this branch, one is happy to observe closer and closer conformity to higher and higher standards. Credit must of course be given to the glass makers, especially Corning. But such important things as aging, annealing or seasoning; blowing bulbs with walls of uniform thinness; meticulous pointing at three, four and even five transformation or other reference points; purifying mercury; permanently coloring alcohol; minimizing thermal lag in bulb chambers and conducting baths; preventing tube slippage without pinching—all these are up to the individual thermometer manufacturers, who therefore deserve the credit. To say nothing of keeping prices low while the shelves of numerous distributing branches sag under the weight of large assortments.

One wishes that one could report that the gallium-in-quartz thermometer had been promoted from the laboratory market to the plant market, but this has not officially happened and there is as yet no handy, simple visible-column thermometer on the industrial market for measuring temperatures above 1000°F. The commercial gallium-in-quartz thermometer when it appears (this year, perhaps?) will probably give as reliable indications at 1700°F. as are given at 950°F. by mercury industrial thermometers with high-pressure nitrogen filling, special bulb glass, special capillary glass and special bulb-chamber construction to prevent erratic changes in bulb volume —essential features which make them rather costly.

2. DIAL THERMOMETERS—Foxboro has just brought out, in time for this review, a duplex long distance dial type instrument equipped with special internal electric contacts carried by one of the pointers. These contacts are so arranged that the contact is closed when the second pointer is 5°F., above the first. A stop arrangement is also provided for closing

*Engineering Editor

the contact when the pointer carrying the contact drops to 40°F. In effect, the thermometer is an electrical controller with a variable control point determined by the outside air temperature. The contact is arranged for use with a relay which carries the load current of a heater. It was developed by Foxboro to prevent condensation and freezing of moisture inside oil



(View with cover open) (Internal View)
Foxboro Duplex Indicating Thermometer with Internal Electric Contacts.

switches at sub-stations. A solution to this problem was obtained by providing a heater in the oil switch and by developing an instrument to turn on the heater should the outside air temperature increase 5° above the inside temperature of the switch, or should the temperature drop to 40°F. This instrument appears to belong further down in this review, under automatic controllers, but Foxboro calls it a thermometer, so there it goes.

3. ELECTRICAL RESISTANCE THERMOMETERS—No new development reported in the indicators. See below for new controllers of which the primary element is or may be an electrical resistance bulb.

4. INDICATING PYROMETERS—Thwing has brought out the new "Model 30," a rugged and compact unit combining an indicator and switch in a single fume- and dust-proof aluminum case. It will withstand vibration and is particularly adapted for use under adverse conditions such as prevail aboard ships, in chemical, lime, cement plants, etc. The indicator is equipped with a galvanometer designed and constructed for use with thermocouples exclusively. The moving coil is mounted at a distance from the center of rotation more than twice that usually employed in stock instrument galvanometers, thus doubling the torque. The magnetic field is concentrated in a single air gap, also increasing the value of the torque and permitting the use of stronger springs, which make the instrument practically free from zero creep. The galvanometer is dead beat, especially well damped and there is no quivering of the needle. In the switch the blades assembled in a strong clamping device which is a single casting, and are further reinforced with a bronze leaf spring, so that good positive contact is assured at all times. The contacts and contact ring are mounted on a bakelite base. Contact position is self locating. The connections from thermocouple to switch are very easily made. . . . The Leeds & Northrup Company has made several improvements in their optical pyrometer. It

can now be furnished with special guard for protection against spattering of molten metal; it now has a double slidewire rheostat; it has been made dust-proof; and it is equipped with rubber feet for protection against shocks. . . . The General Electric Company brought out a pyrometric system[1] for indicating aircraft engine temperatures, consisting of a thermocouple, twin-conductor leads, and a cold junction temperature-compensated, remote-indicating instrument. Cold junction compensation is accomplished by the use of G-E metal No. 747, whose magnetic permeability changes with changes in temperature. Under ordinary flying conditions accuracy is within 3°F. The thermocouples are not imbedded—one form has a threaded connection, requiring a quarter-inch tapped hole; another is in the shape of a washer to go between spark plug and cylinder head. . . . Westinghouse has brought out a system for directly indicating the temperatures of imbedded thermocouples in electrical machinery.[2] Copper to copper-nickel thermocouples are used, together with an electrical method of cold junction compensation, with balance point at 30°C. and independent of control voltage, and a sensitive but reliable millivoltmeter. Though this particular application is within the thermometric range, this development must be listed under pyrometers. . . . Claude S. Gordon Co. has brought out a new double pole platinum contact switch suitable for use with any make or type of pyrometer, and also a dust-proof cabinet combining multi-point switch with housing for any indicating pyrometer. . . . See also under Controllers, Pyrometric, Indicating.

5. PYROMETRIC ACCESSORIES—The Thwing "Treasure Chest" is a new potentiometer type pyrometer and thermocouple checking set, the only instrument of its kind which contains the "Electrocrite," by the use of which it is possible to pass a current into a pyrometer that is being tested and to adjust this current to correspond to the different thermocouple values at the different temperature points. In this way, a check over the entire scale range can be taken in a few minutes. Any make or type of pyrometer, indicating or recording, can be checked. Thermocouples can also be checked very quickly as stations are provided on the instrument to which the standard thermocouple and the thermocouple to be tested are connected. By means of a double throw switch, a reading is taken on one and then the other and the readings compared. The Treasure Chest is said to be "the most compact, convenient and complete" instrument for checking pyrometers and thermocouples.

5. REGISTERING INSTRUMENTS—The only new development reported is the minimum-registering airplane strut thermometer[4] described by H. B. Hendrickson of the Bureau of Standards.

II. RECORDING

1. THERMOMETERS—Tagliabue has brought out its line of round-form instruments, including flush types for panel boards. . . . The Moto Meter Gauge & Equipment Corp., has added a precision recording thermometer to their line of instruments. Its element consists of a bulb, capillary tube and a Bourdon tube filled solidly with a special liquid which has an

[1]Instruments, December 1929, pages 476-477
[2]Instruments, April 1929, pages 135-140
[3]Instruments, December 1929, pages 484-486
[4]Instruments, September 1929, pages 323-324

equal co-efficient of expansion over its whole range. Each chart is individually calibrated to the exact temperature of the bulb proper and then compared with the master instrument. It is not affected by the altitude nor by the temperature of the room in which it is located, as readings represent true temperatures at the point where the bulb is located. A compensating spring takes up any difference between the bulb and room temperature and automatically resets the pin at the point on the chart corresponding to the bulb temperature. Unlike all other solid liquid filled recording thermometers, this instrument has a one to one ratio movement, resulting in the elimination of levers, hair springs, screw gears and other delicate parts subject to continual wear and adjustment. The one to one ratio movement also insures the transmission of greater power to the pen . . . Taylor brought out in October a "Four-in-One Sanitary Milk Connection" by means of which one recording thermometer may be connected to all standard types of dairy apparatus fittings. It consists of seven pieces which, when combined in the proper order, make up either a sanitary ferrule fitting, or a three-quarter inch thread union hub fitting, or an I. A. M. D. coil vat fitting, or an I. A. M. D. glass lined tank fitting.

2. PYROMETERS, POTENTIOMETRIC—The new Wilson-Maeulen null-method potentiometric recorder[5] has just come out. Its most important apparent feature is the twelve-inch chart—the widest chart of any pyrometer recorder. This instrument is applicable also to service as a recording Wheatstone Bridge in electrical resistance thermometry. It embodies a number of other new features of mechanical and electrical design. When the measured voltage from the thermocouple changes, due to change of furnace temperature, the galvanometer pointer deflects in the corresponding direction. Once every ten seconds a boom descends on the pointer and locks it fast and rigid. Two sensing fingers moving in a vertical plane explore horizontally on each side for the location of the pointer, and if either finger finds the pointer deflected and away from its central, or null position, a roller ratchet dog is released by the finger and a drum proceeds to turn. Around the drum is wound a single turn of violin string, with its end passing over pulleys and attached at opposite sides of a carriage adapted to travel back and forth across the whole instrument. The carriage carries the recording pen and a contact brush that rides upon the potentiometer slide wire. The selective operation of the drum's rotation, both in direction and extent, moves the contact on the slide wire so as to bring the galvanometer pointer back towards its null, or undeflected position, and at the same time moves the recording pen to record the furnace temperature on the chart. The recording pen (which has a metal tube siphon) and the slide wire contact are integral and cannot get out of relationship to each other. A new special red ink has been developed. Another new feature permits adjustment to accomodate for any variation in the width of the chart paper due to atmospheric conditions. The instrument case opens diagonally, making the entire mechanism easily accessible. The slide wire is wound on a straight rod, located in front just above the chart where it is easily cleaned. Slide wires are easily removed and replaced and are interchangeable.

3. PYROMETERS, GALVANOMETRIC—The new Thwing Model 28 Metal case recorder contains a smaller number of working parts than any other multiple record recorder, and does not use ribbons or carbons of any

[5]Instruments, November 1929, pages 407-409

kind. Records are made with the Thwing dot and dash method of recording. The inking is done by a capillary ink well which is mounted at the zero position of the pyrometer. The pointer dips into this ink well, and is gently depressed so that it touches the chart. Multiple records are obtained in the form of a dot, a light dash and a heavy dash. The advantage lies in the fact that it is not necessary to depress the galvanometer pointer with a great amount of force. The Model 28 Recorder has chart reroll as standard equipment and it is dust-fume-and moisture-proof. Also foolproof: Just as soon as the recorder door is open the galvanometer pointer will rise off the chart if it should be depressed at the time. These recorders can be used with thermocouples, radiation receiving tubes and electrical resistance thermometer bulbs.

III. RECORDER-CONTROLLERS

1. THERMOMETRIC—Tagliabue has brought out a double system recorder-controller housed in a square case, which actuates air relays for the control of two sources of heat supply. The principal application reported is lumber dry kilns. The novel feature is a method of so regulating the "mode" of control that any effect, from the straight on-and-off to the close throttling, may be obtained in either or both of the systems. . . . Another new recorder-controller is reported by Foxboro. It is a psychrometric instrument for the automatic control of relative humidity at atmospheric temperatures. The primary element, which responds to changes in relative humidity regardless of temperature and which operates the pen arm of the recorder, is a strip of hygroscopic animal membrane.

2. PYROMETRIC—See below under "Automatic Controllers, Pyrometric."

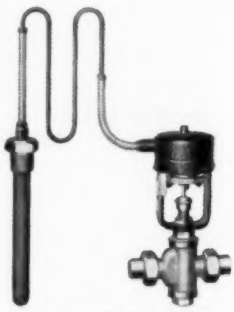
IV. AUTOMATIC CONTROLLERS, THERMOMETRIC

1. GLASS THERMOMETER, ELECTRIC RELAY—In this class, which comprises mercury-in-glass thermometers with platinum contacts fused through the glass, the American Instrument Company has brought out the Metastatic Thermo-regulator which, unlike other types, has an adjustable temperature setting so that contact can be made at any predetermined temperature. In connection with this contact thermometer, the same company has brought out a new mercury relay rated up to 10 amperes at 110 volts, which will operate from a single dry cell.

2. FIXED-STEM, SELF-CONTAINED RELAY—The Mercoid Corporation has recently announced the Pyratherm, a controller designed for domestic and industrial oil burners. The sensitive element is a bimetallic coil which rotates an operating shaft with changes in temperature, the shaft protruding outside the stack and into the instrument case where it actuates the contacting device. One of the new models embodies a safety cutout known as the Adjustatherm, which automatically trips up a switch and stops the burner motor if the oil is not ignited. The Mercoid Corporation has also brought out an improved tipless tube mercoid switch in single pole or two-circuit models, with ratings up to 10 amperes at 110 volts. One model is especially designed for high starting loads.

3. SELF-OPERATING, REMOTE BULB—The Fulton Sylphon Company has brought out a new temperature regulator, known as the No. 921, a neat and compact device unaffected by temperature fluctuations at

the valve end either above or below bulb temperature. It has an indicating scale for setting at the desired temperature. No. 921-Z is a similar regulator but designed for refrigeration applications where a cooling medium must be controlled.



Fulton Sylphon Temperature Regulator

4. DOUBLE-BULB, MERCURY SWITCHING—The American Radiator Company recently announced a new model DMS (No. 848) Mercoid control for unit heaters which "greatly reduces the cost of installation over earlier methods. There are no steam connections and no extra wiring or conduit. It combines two instruments in one: first, automatic control of room temperature by starting and stopping the fan motor according to changes in air temperature and second, an automatic cut-off, which stops the motor or prevents it from starting, in case the heating surface is cold. The fan cannot start unless the heating surface is filled steam." Two primary elements are used, each operating the same Mercoid Switch. The lower element is actuated by the temperature of the air which is drawn over the element by the fan. The upper element is a capillary bulb, four feet of which is wound around the condensation or drip line. As long as this pipe is cool, change in air temperature cannot start the motor. When steam fills the heating surface and the drip pipe warms to 160°, the upper element releases the lock, allowing the lower element to start and stop the motor to maintain the desired temperature.

5. REMOTE-BULB, AIR-OPERATED REMOTE-CONTROL, INDICATING DIAL ON CASE—This title describes the convenient new

New TAG Indicating Controller External View

Tagliabue Indicating Controller. As the illustration shows, there is virtually a dial indicating thermometer on the face of the round case, as well as a tell-tale gauge for the air supply and another gauge showing the opera-

tion of the diaphragm-motor valve. The primary element is a mercury-filled system with full compensation for temperature fluctuations along the connecting tube, which may therefore have a length up to 150 feet. "Swing control," another new Tagliabue development, permits adjustment of valve action.

6. IMPROVED CAPSULE—In all air-operated controllers having vapor tension primary elements, the expansion capsule or diaphragm box which actuates the pilot air valve is a very important part. Taylor recently announced that after six years of research a capsular diaphragm had been developed resembling the conventional type in appearance but containing an inner envelope of comparatively thin metal. In this new Tycos inner seal capsular diaphragm, the outer chamber merely serves to limit the movement of the envelope and is assembled without solder.

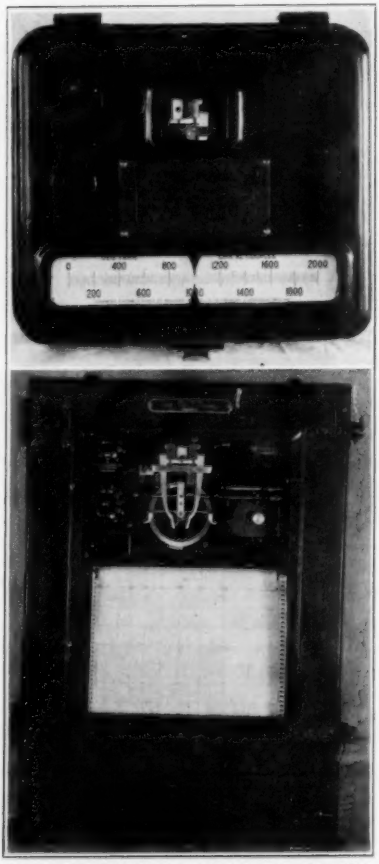
V. AUTOMATIC CONTROLLERS, PYROMETRIC

The developments in this group of instruments do not lend themselves to methodical classification as above. For example, one new system might be described under several headings. Therefore we must simply go down the list of reporting companies, alphabetically.

BROWN INSTRUMENT COMPANY—One of the most valuable contributions to the needs of industry has been developed by this Company during 1929 in the perfecting of an improved "follow-up control" permitting closer regulation than has hitherto been obtainable under conditions where the "on-and-off" type of control is unsatisfactory. In many applications conditions demand a gradual throttling action of the control valve, and if the time lag is appreciable the step-by-step control will set up excessive hunting. The new follow-up type of control can move a valve in very small steps and produce the so-called throttling action which is considered desirable in most control applications. This gradual throttling action is obtained without sacrificing the exactness of the control setting. The term "follow-up" is used to describe the action of the selector table as it follows the pointer, and any correction in the valve position which is accompanied by a movement of the selector table toward the pointer is called a "follow-up" correction. Causing the table to follow the pointer avoids overcorrecting, because with each correction the selector table moves along the scale until the center step of the table is at the position indicated by the pointer on the last depression. If the pointer has moved in the meantime, another correction will be made, but if the pointer has not moved, no "follow-up" correction will be made. It is evident that the "follow-up" corrections are made in accordance with the rate of change of temperature, that this action produces a definite valve position for each position of the pointer, and that the "follow-up" corrections tend to oppose any change in temperature. This holds true whether the temperature trend be away from the control setting or toward the desired temperature. The follow-up device is therefore a stabilizing factor and tends to prevent any change in the temperature. It ceases to function whenever the pointer remains stationary, although the temperature may not be at the correct value. The term "escapement" is used to denote the action of another element in the control instrument. As explained above, the follow-up corrections produce a different valve position for each position of the pointer. Accordingly, if changing conditions require that the valve remain in a new position the pointer and selector table would also remain away from the control setting.

In order to maintain an exact control setting, some means must be provided to effect a shifting in the relative positions of the valve and the selector table. This may be accomplished in one of two ways: (1) Shifting the table while the valve remains stationary. (2) Shifting the valve while the table remains stationary. The "escapement correction" is made by the center contact lever in either case. The action of the escapement correction does not depend upon the rate of change of temperature, but upon the position of the selector table with respect to the control setting. It recognizes a departure of the selector table from the control setting and functions whenever the pointer is depressed upon the center step of the selector table. The two elements, in combination form a control device which recognizes the three important factors: Rate of change, Deviation from the control setting and Direction of trend.

LEEDS & NORTHRUP—Mr. Garretson of Leeds and Northrup presented his Company's portion of this review himself and did it so tersely and concisely, and with such a keen sense of proportion, that little editing was necessary: "(1) The new L & N Automatic Indicating Controller. This has been designed to fill the demand for an automatic controller with a convenient temperature reading device for use when a record is not necessary. It has a wide, open scale, marked off with large numerals, readable at a distance of ten feet. It is equipped with two pointers, one showing the automatic control setting and the other showing the actual temperature being maintained. The temperature is set by means of a knob on the outside of the case. (2) The new L & N Automatic Rotating Glass Pot Controller. This is a specially built controller substituting a fixed focus radiation pyrometer for the customary thermocouple. It can be used on other high temperature applications, such as the control of open hearth furnace reversals. The controller has the usual L & N automatic control mechanism, but the circuit is special for this particular controller, being however a potentiometer type with measurement unaffected by length of lead wires. (3) The new L & N Automatic Anticipating Controller. This is of special interest to oil refiners,



Above—The L & N Automatic Indicating Controller
Below—The L & N Potentiometer Controller for Rotating-Glass-Pot Temperatures.

open hearth men and blastfurnace operators. It varies but little in appearance from the conventional L & N automatic controller. Additional contacts on the front of the mechanism are of a new type arresting the valve motion when the temperature trend changes direction. The actual fluctuation, the temperature trend, and the speed of response are all taken into consideration, automatically by this Anticipating Controller. It reduces total fluctuation of temperature to a minimum and varies the speed of control according to the rate needed to insure the most satisfactory or quickest possible return to desired temperature." . . . Another tamer of electricity close to the goal of ideal control!

REPUBLIC FLOW METERS CO.—This Company brought out a new indicating controller which was listed and described in the May issue.[6] What appear to the reviewer to be important developments were not emphasized, however, and now deserve honorable mention. First, the fact that the only contacts made and broken in the entire control circuit are made and broken inside a mercury switch of novel design capable of handling currents up to 25 amperes. This is a gas-filled switch embodying an inner tube of quartz which is insulated from the glass sealing tube. The contact is mercury-to-mercury and occurs inside the quartz tube. This entirely eliminates the need for control panels and relays except, of course, in the case of large electric furnaces. Temperature is measured by a double-pivoted millivoltmeter system which has the highest resistance of all instruments of that type on the market, so that variation in length of lead, changes in temperature along connecting wires, or poor contact, has little effect upon the accuracy of indications. The pointer is not required to do any mechanical work whatever, its mere position with respect to the target actuating the motor-driven mechanism at intervals which may be varied to suit the rate of heat supply of the controlled furnace. The scale is six inches long, with open graduations in the usual ranges. It is possible to place any two scales together, one being over the other but without automatic cold junction correction. This controller is sensitive to a temperature change equal to one-tenth of one percent of the full scale reading, which means that on a 0 to 2000°F. scale it will control within a two-degree temperature change. (One may well ask, referring to the remark at the beginning of this review, whether any delicate "scientific" instrument, specially built for use in any scientific research laboratory, tirelessly controls to plus or minus one-tenth of one percent of its range). These features, and others which were mentioned, combine, in the opinion of the present reviewer, to make this instrument a superlatively effective controller of the "on-and-off" type.

VI. AUTOMATIC CONTROLLERS, SPECIAL

NEW TAG CYCLE CONTROLLERS—One model of the TAG cycle controllers, designed for the automatic operation of a tire press, was described in the "New Instruments" section last April.[7] By means of eight cams, two electric clocks, air and electric relays, safety interlocks and other features, this controller not only supervises the curing process with its heating period, holding period, steam blow-off, admission and draining of cooling water, and final mold warming, but it also regulates the high pres-

[6]Instruments, May 1929, pages 183-184
[7]Instruments, April 1928, pages 133-134

sure air to the air bags and automatically tests for leakage, so that the cure cannot begin if bag leakage is apt to spoil it or if the hydraulic pressure is not above a certain minimum. All in all, an amazing product of American inventiveness, which we had the pleasure of placing between the Sperry gyroscopic pilot ("Iron Mike") and the Coast Survey's tide predictor in the new edition of the Encyclopaedia Britannica . . . Another type of the TAG cycle controller appeared in the summer, designed for platen presses in which rubber or plastic composition articles are molded and cured. In contrast to the tire press, where the curing cycle requires more than two and a half hours, the platen press is a "speedup" machine and the principal functions of this TAG cycle controller are to time the cure to the second, to prevent premature opening of the press, to open it automatically at the end of the cure, and to provide safety interlocks of all steam, air, and high and low hydraulic ram pressure lines. A graduated cam, visible through a window, shows at a glance how far the cure has proceeded. An emergency lever serves the following purposes: If the operator starts the controller without the molds having been properly centered or before either attendant has had a chance to get his hands clear, and discovers the unsafe conditions as the press is closing, pulling the emergency lever releases the hydraulic and opens the press. The emergency lever may also be used for "bumping" the press without operating the counter which is so connected that it functions only with the termination of the cure . . A third type of the TAG cycle controller has recently been devised for use on individual tire vulcanizers. This controller automatically closes and locks the vulcanized and supervises the curing cycle, finally unlocking and opening the press. Another model of this type has been developed for the automatic operation of tube mold machines.

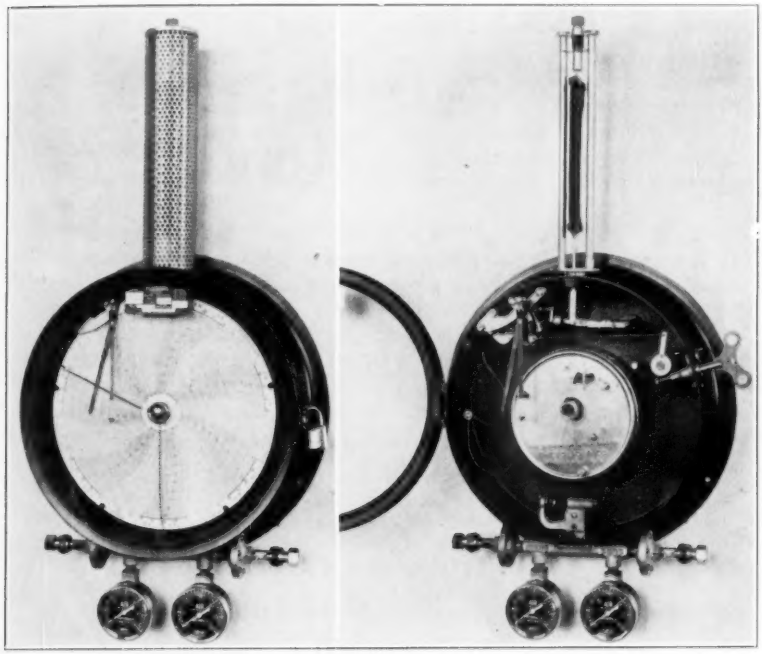
FOXBORO KILN BOY—This new instrument[8]—or, rather, complete system—comprises their standard humidity recorder-controller with auxiliaries for regulating both the steam to the heating coils and the spray line. It automatically changes the wet and dry bulb control points, according to any particular drying schedule, under the control of a characteristic sample of the lumber being dried. The scale on which the sample is placed is of the pneumatic type, the weight of the moisture in the sample regulating the air pressure. This makes it possible not only to control the humidity but also to record the rate of drying in terms of reduction of weight of the sample board.

BRISTOL HOT BLAST RECORDER-CONTROLLER—This extremely important contribution to blast furnace economy was described last month.[9] The automatic operation of the mixing valve does away with the present enormous fluctuations in the temperature of the air entering the hot blast main from the stoves. Bristol has conquered the difficulties of mixing valve operation by automatically varying the speed of the valve motor. The Bristol system comprises a strip chart recorder in addition to the pyrometric controller and its adjuncts.

AUXILIARIES—The Automatic Temperature Control Company modestly denies that its products can be classified under "temperature instruments," but it does manufacture an extensive line of relays, control stations, time cycle contactors, regulating valves, position indicators for valves, dampers, etc., interrupters and—yes, even electric temperature

[8]Instruments, June 1929, pages 217-218
[9]Instruments, December 1929, pages 480-484

controllers. Its principal field, however, remains that of devices controlled by the instruments made by instrument makers. This Company reports developments in 1929 in the way of die casting of parts to make for interchangeability, new ways of interlocking the wiring up of their equipment to obtain better results under practical working conditions in the control of industrial furnaces, etc.



(Exterior) (Interior)

Foxboro Relative Humidity Recorder-Controller

The Brown Instrument Company, Philadelphia, has appointed as its Chief Engineer, Mr. E. B. Nichols, well known for his previous connections, and his activities in the A. S. M. E.

Mr. Nichols, who is an M. E. graduate of North Carolina State College, was at one time Chief Engineer of the Pfaudler Company, Rochester, N. Y., subsequently holding the position of Chief Engineer of the Victor Talking Machine Company, Camden, N. J. Later he became associated with the Bell Telephone Laboratories, which connection he severed to join The Brown Instrument Company organization.

Mr. Nichols will act in an administrative capacity, supervising the work of the engineering staff. The past achievements of Mr. Nichols, his broad executive experience and ability in handling men and materials equip him particularly well for the varied and difficult problems presented in his new work.

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Recent Advances in Colorimetry

*Foster Dee Snell**

Historically the methods of colorimetric determination vary from a simple comparison of two test tubes held in the hand, through the use of the balancing type instruments, to photoelectric comparison. The advances of the past few years have been largely in refinement of apparatus previously used. Such refinements are neither minor nor unimportant. The development of methods of pH determination and their adoption by industry have been particularly impressive.

pH INDICATORS.—The range of such indicators available commercially has been extended so that pH 0.2 to pH 13.6 can be determined with an accuracy of ±0.1 unit in all cases, and of ±0.05 unit with many indicators. Universal indicators are available and permit estimation of pH within ±0.5 unit from pH 2-12 by a single test. Several new mixtures have been proposed.[1,2].

The use of nitrophenols has been expanded. A simple soil test kit has been made available for the amateur gardener, using a mixed indicator for the range pH 4.0-8.0. More complete and accurate sets are also available.

Clark[3] has simplified the approximate estimation of pH by providing a colored chart of the Clark and Lubs indicator. This is also sold as a separate sheet.

SERIES OF LIQUID STANDARDS.—The roulette comparator is well known to readers of the technical journals. A recent patent[4] covers the use of rectangular sealed ampoules instead of the usual cylindrical ones, particularly for hydrogen ion determination. In another type the sample with indicator is matched against the sample without indicator by interposing suitably colored wedges, either of solid colored glass or hollow glass filled with colored solutions[5].

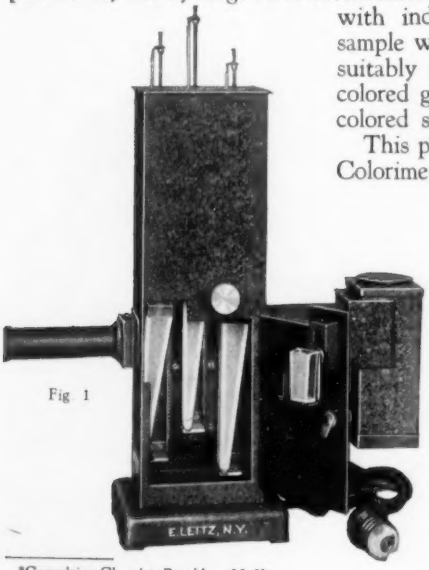

Fig 1

This principle is utilized in the Leitz Bi-Colorimeter[6] shown in Fig. 1. This is designed primarily for pH work in 2 colors. In many cases a neutral color wedge is necessary so that 3 wedges are provided. The greater thickness of glass on the wedge side of the field is compensated by a series of glass plates in a holder on the sample side of the apparatus. An accuracy to 0.02 unit of pH is obtainable in some ranges.

The same principle in a more complex form has been applied to a rotating colorimeter[7].

*Consulting Chemist, Brooklyn, N. Y.

1. M. Kolthoff, Pharm. Weekblad. 66, 67-70 (1929).
2. H. W. Van Urk, ibid 66, 157-62 (1929).
3. The Determination of Hydrogen Ions, Williams and Wilkins Co., 3rd Edition, 1928.
4. Asamatsu Hyuga, U. S. Patent 1,659,529, Feb. 14, 1928.
5. Eugene D. Stirlem, U. S. Patent 1,616,092 Feb. 1, 1927.
6. V. C. Myers, J. Biol. Chem. 54, 675 (1922).
   Rene Andre Legendre, English Patent 285, 848 (1927).

SERIES OF GLASS STANDARDS.—The basic instrument of this type best known is the Lovibond Tintometer. A recent development[8,9] has been the Rosenheim-Schuster colorimeter. In this Lovibond color glasses mechanically shifted for comparison with the sample in a cell or tube of fixed thickness. The glasses are in horizontal carriers controlled by colored knobs on the front of the apparatus. Seven scales are ordinarily used; red, blue and yellow from 0.1 to 1.0 and from 1.0 to 10. The seventh carrier contains additional highly-colored standards. Provision is made for the insertion of neutral grey slides if the sample is too brilliant in color. The instrument was originally designed for work with vitamin A where the comparison must be made in 30 seconds by one method or in 1 minute by another. Recently these methods for vitamin A have been seriously questioned as to accuracy[10] but other applications of the equipment have been developed.

The Hellige colorimeters are a series of three types designed primarily for pH work. The first, shown in Fig. 2, is the standard type. The sample

Fig. 2

in a standard cell is compared with a series of glass discs mounted in a circular rotating holder. More recently discs for determination of iron, lead, copper, titanium and chlorine have been made available. The second form is a simplified, easily portable instrument using the same color discs. In the final and simplest form the sample, in a capillary tube, is compared with a series of rectangular glass standards.

An instrument[11] for the vegetable oil industry carries the Lovibond glasses in 4 discs, respectively 0.1-0.9 red, 1-10.0 red, 1-9 yellow and 10, 20, 30, 35 yellow. A similar instrument has been designed for petroleum oils[12].

[8]Otto Rosenheim, Biochem. J. 21, 1329-34 (1927); English Patent 28,981 (1927).
[9]Otto Rosenheim, E. H. J. Schuster and Tintometer, Ltd. English Patent 299,194 (1927).
[10]Philip B. Hawk and others.
[11]H. S. Bailey, J. Oil and Fat Ind. 2, 8-13 (1925).
[12]J. P. Bader U. S. Patent 1,629,809 (1927).

A modification of the Duboscq instrument replaces the standard solution by a colored glass in one of the plungers[13].

RELIABILITY OF COLOR GLASSES.—The reliability of color glasses in grading of vegetable oils is of great importance. For Lovibond glasses between 35 yellow and 35-yellow-7.2-red on the Priest-Gibson scale an increase in temperature of 25° C. is practically equivalent to addition of 0.2 red unit[14]. The temperature effect in grading of cottonseed oil is therefore negligible. More recent work[15] on 65 35-yellow glasses has shown the discrepancy from the Bureau of Standards set as not more than 2-3 times the least difference perceptible with certainty by the best observers under the most favorable conditions of observation. The variation from the average of 65 glasses was much less. Only 3 badly marred glasses were unsuitable for use.

BALANCING TYPE COLORIMETERS.—A balancing type colorimeter constructed of Hehner cylinders connected to reservoirs with rubber tubing has recently been described[16]. The Campbell-Hurley type of colorimeter has also been described using Nessler tubes for simplification[17].

The so-called Universal Colorimeter is a combined colorimeter and nephelometer, provided with suitable attachments for filling the functions of a Duboscq colorimeter and Kober nephelometer. The Burker type is also a Duboscq, with the cups totally enclosed.

Immersion colorimeters have been discussed but except in one or two specific industries do not appear to have been adopted.

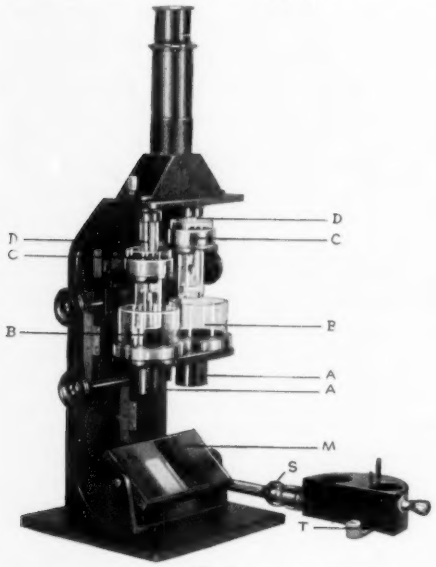

Fig 3

A recent modified Duboscq instrument[18] replaces the single cups with two concentric cups. Two standards of differing color can each be varied to match two color changes in the standard. This is particularly applied to pH determination. Such an instrument is shown in Fig. 3. A-A are auxiliary cups for use in the Walpole technique. B-B are the additional pair of cups into which the usual cups C-C dip. D-D are the plungers, M the mirror and S and T auxiliary equipment for maintaining any desired temperature. An instrument with 3 such cups has also been described. A micro Duboscq colorimeter requires only 1 cc. of sample[19]. Reflection scales are relatively new, by which the position of the cups can be read from the eyepiece rather than from a scale on the back of the instrument.

[13]W. L. Patterson, U. S. Patent 1,643,515 (1927).
[14]Deane B. Judd, Bur. Stan. Jour. Res. 1, 866 (1928).
[15]Irwin G. Priest, Deane B. Judd, K. S. Gibson and Geraldine K. Walker, Bur. Stan. J. Res. 2, 793-819(1929).
[16]R. C. Frederick, Analyst, 52, 469-70 (1927).
[17]J. H. Yoe, Ind. Eng. Chem. 19, 1131 (1927).
[18]Carl Zeiss, Inc. English Patent 280,552 (1928).
[19]H. Kleinmann, Chem. Fabr. 1928, 263-4, 278-9; Bio-chem. Z. 179, 276-86 (1926).

PHOTOELECTRIC COLORIMETERS.—Progress in measurement of light by its effect on a photoelectric cell has been marked[20, 21, 22, 23, 24]. So far no commercial instrument for the purpose is widely marketed in the United States. At the time of writing at least one type is being developed commercially[25].

When available various types will colorimetrically estimate gases, liquids or solids; transparent, translucent or opaque over any portion of the visible spectrum or in the ultraviolet. The estimated accuracy is to 0.1% whereas the human eye is various estimated as accurate to 2-5%. With the proposed instrument it is expected that a determination will require from 1 to 10 minutes.

A semi-automatic colorimeter controls chlorination,[26] using the benzidine-potassium iodide method and requires only observations by the operator.

SCOPOMETRY.—This term has been applied to the use of a new instrument shown in Fig. 4, with a direct reading scale[27]. The end point is obtained by the disappearance of an illuminated target against a field of much lower intensity. This is caused by adding to the density of the sample to be measured a second density by use of a variable neutral wedge. The method is applicable to colored solutions by the introductions of a complementary color screen and to turbid solutions. The wedge is calibrated from a zero point for the individual observer, which corrects for many of the usual errors of colorimetry. By having calibration scales for various determinations the use of standards is unnecessary. The method does not equal in accuracy the more refined colorimetric determinations.

Fig. 4

MISCELLANEOUS.—Colorimetric estimation of the degree of detergency has been quite unsuccessful when the soiled fabric was compared with either color plates or standard soiled fabrics[28]. Application of the photometer[29] or of the tintometer[30] in this type of problem has been successful.

[20]S. P. Reimann, Proc. Soc. Exp. Biol. Med. 23, 520-3 (1926).
[21]C. H. Sharp and C. Kinsley, Elec. World 87, 823 (1926).
[22]L. B. Desbleck, Electrician 99, 8 (1927).
[23]Karl S. Felix, Helmrich and Wanderscheck, Wochschr. Brau 45, 312-6 (1928.
[24]B. F. Stockhausen and F. Windisch, ibid 45, 231 (1928).
[25]Harold D. Ellsworth, Meeting of American Oil Chemists Society, New York, Nov. 14, 15 (1929).
[26]G. Baganz, Chem. Gabr. 1928, 358.
[27]William G. Exton, U. S. Patent 1,635,470 (1927); U. S. Patent 1,717,702 (1929).
[28]L. F. Hoyt, J. Oil & Fat Ind. 4, 29-34, 66-9 (1927).
[29]F. H. Rhodes and S. W. Brainard, Ind. Eng. Chem. 21, 60-68 (1929).
[30]Unpublished work of the writer.

LIGHTING.—In one form[31] artificial light from a 100 watt lamp is reflected from a standard white powder, as usual with the Lovibond Tintometer. The powder is covered by a slightly bluish glass of a value not less than 0.5 or more than 1.95 on the Lovibond scale and not more than 0.15 inch thick. Such a glass corrects for the excess of red and yellow rays from the lamp.

Many designs of lamps have been offered. The errors due to variable lighting have apparently become more widely appreciated, resulting in greater use of standard light sources. Whatever the design, these usually consist of a blue screen to compensate for the yellow rays of the artificial light and to approximate northern sky light.

[31]Tintometer Ltd. English Patent 263,924 (1925).

INSTRUMENTS BOOK SHELF

The books reviewed in this section can be supplied by Instruments Book Shelf, Instruments Publishing Company, Pittsburgh, Pa.

GAUGES AND FINE MEASUREMENTS. *F. H. Rolt.* MacMillan Company, New York, 1929. Cloth. Vol. I. Standards of Length, Measuring Machines, Comparators, 366 pages, 253 figs. Vol. II. Limit Gauges, Measuring Instruments, General Methods of Measurements, 357 pages, 353 figs. Price both volumes $14.50 postpaid.

The instruments used for the measurement of parts during manufacture have passed through various periods of development. The earliest one was marked by the use of an ordinary wooden scale together with whatever other devices were at hand or could be supplied by the ingenuity of the machinist. This was followed by the use of the steel scale and the caliper. Next came the use of micrometers and specially designed mechanical measuring tools. Then optical apparatus opened an avenue for the accomplishment of many measurements heretofore deemed impossible.

Up until the second half of the 19th century, the greatest accuracy of measuring tools was 0.005″, up to the beginning of the 20th century this was increased to 0.0005″, and now instruments are available, which are capable of measuring to an accuracy of 0.000001″. It may come as a surprise to many that measurements of this accuracy are a practical necessity to meet the requirements of industry.

With a greater appreciation of the advantages of accurate measurement has came a steady demand for further development and new methods and applications are continually being evolved. The present time marks a fairly well-defined stage in the evolution of suitable methods and devices for measuring with speed and precision.

These two volumes, based on the author's article on "Gauges" in the Dictionary of Applied Physics are therefore appropriate as they take stock of the present status of this subject. Very excellent bibliographies are given at the end of each chapter, which will permit looking further into each of the divisions treated. The foreign and domestic literature is represented in the references, a point for which the author is to be commended. Appendices contain a considerable amount of amplifying information, including specifications of the wave-lengths commonly used in optical interference measurements, information of standardized equivalents in decimals of an inch for the various gage numbers, notes on the testing of a circular dividing machines, etc.

A knowledge of the principles and methods employed in fine measurements is of the first importance in every modern tool room, research laboratory, etc., and these two volumes therefore fill a decided need. The mechanical engineer, the instrument designer, the machine-tool builder and the machine tool user will find these books of immediate value. They open a broad field of information backed by the high standing of the author.

Precision measuring tools on the market are covered without partiality as to country, American and German instruments are covered together with the English. Only one omission was noticed, in the case of measuring machines, linear and circular dividing machines and microscopes, no mention is made of the Gaertner Scientific Corporation Chicago.).

Chapter XIV of Vol. II, "Notes on Design of measuring Instruments" should especially interest the instrument manufacturers. Several examples showing how the application of correct principles in design has enabled instrument makers to overcome many of the difficulties and sources of error which so frequently arise in connection with accurate measurements are given.

A third volume on the measurement of screw gages is in preparation.—Richard Rimbach.

RECHERCHES METROLOGIQUES SUR LES ACIERS AU NICKEL. *Ch Ed. Guillaume, Director,* Bureau International des Poids et Mesures. Published by the Bureau, 1928. Cloth 12½ x 9½ inches. 242 pages. Price 102 Francs.

A man may be investigating difficult problems, sometimes tedious, not seldom involving years of time, but the majority of us look for their solution, expect to terminate the work either with some direct results or by setting definite limits to the undertaking. It takes an exceptional man to spend a lifetime in a study of a subject knowing that it will not be completed and will not bring any radical changes in the conception of the subject though furnishing material of utmost value to the later workers.

Being in charge of the Bureau international des Poids et Mesures Mr. Guillaume came in contact with the materials suitable for the manufacture of the primary standards and, wishing to check the constancy of the properties of metals started in 1891 the study of changes produced by time in measurable properties of a low expansion group of iron nickel alloys including invar. The present book presents the results of the work conducted continuously for more than a quarter of a century.

For a man in the shop the book hardly will be of an immediate value, but for those connected with the use or manufacture of accurate instruments or measuring devices this work opens a broad field of information backed by the high standing of its author. The reader is introduced to the methods giving results in the range of accuracy required for this type of work, properties affected by the time are discussed and a large amount of data fills the long existing gap in this field. — John D. Gat.

Die Organisation der Waermeueberwachung in technischen Betrieben, *Hans Balcke*. R. Oldenbourg, Munchen, 1929. Cloth, 5¾ x 8¾ inches. 312 pages, 213 figs. Price 17.50 RM.

The author has made a very commendable effort to produce a complete treatise on the present status of the industrial measuring science in Germany. The book is therefore more suitable for production executives and operating engineers than it is for use as a text book. The material is largely devoted to measurements in boiler plants, other heating processes being given but little attention.

The book is divided into 3 parts: Part I deals with instruments and methods and considers the measurement of liquids, gases and vapors; pressure and draft; temperature, humidity, analysis of the products of combustion, distance transmitting of indications and records. Part II deals with the subject of heat efficiency in small and large boiler plants, furnace and gas producer operation, describing installations in boiler plants and in a steel plant as examples. Part III is devoted to automatic boiler regulation. In this part control of boiler operation is considered in some detail and the devices of "Askania" and "Arca" are described.

The reviewer can appreciate the partiality shown for German instruments as the book will probably have a limited foreign circulation, but he cannot understand the very conspicuous omission of the instruments and apparatus of Siemens & Halske. This is especially evident in the author's consideration of thermoelectric and radiation pyrometers, CO_2 and $CO + H_2$ meters, psychrometers and combustion controls, as competitive equipment is illustrated in each case.—Richard Rimbach.

Hydrogen Ions—Their Determination and Importance in Pure and Industrial Chemistry. *Dr. Hubert T. S. Britton*, Chapman & Hall,Ltd., London, 1929. Cloth 5¼ x 8½ inches, 515 pages, 108figs. Price 25 shillings.

This is the third volume of the series of monographs on Applied Chemistry under the editorship of Dr. E. Howard Tripp. It reviews various theories of electrometric methods for the determination of hydrogen ion concentration, assuming the correctness of conductivity data as leading to the true concentration of hydrogen ions, but does not treat of G. N. Lewis' "Activity" theory. The preparation, uses and limitations of the various cells and electrodes and the measurement of E. M. F. are all given in splendid detail. The treatment of colorimetric methods for pH determination, with detailed discussion of apparatus aad errors involved, is very good.

The chapters on errors in indicator methods, the use of indicators and the preparation of indicators, while very fine in their treatment of the subject matter covered, fall short in that some of the newer indicators have not been discussed. The analytical and industrial applications of hydrogen ion indicators have not been discussed. The analytical and industrial applications of hydrogen ion concentration are particularly well treated.

The importance of hydrogen ion concentration in the electro deposition of metals, leather manufacture, sugar, pulp and paper, brewing, milk, baking, water purification, control of soils, ceramics, textile and dye industries, and ore flotation is emphasized. It is unfortunate that in a book of this nature, each of these subjects can not be given greater space. This book serves to whet one's appetite to look further into each of these subjects, the bibliographies serving as a fine basis.

The chapter on miscellaneous industries treats of the manufacture of sweets, canning of food products, manufacture of fruit jellies, photography, emulsions, soaps, dentrifices, oil water emulsions in petroleum products and fire extinguishing foams. These are merely mentioned as indicative of additional applications of hydrogen ion control.

To the American reader the book might seem somewhat of a disappointment in that the chromium plating industry, and biology from the clinical diagnostic and physiological viewpoints, are hardly mentioned, but in spite of these shortcomings, the book is a welcome collection of data not easily obtainable.—Arthur Schroder.

The Kinematical Design of Couplings in Instrument Mechanics. *A. F. C. Pollard*. Adam Hilger, Ltd., London, 1929. Cloth, 5½ x 8½ inches, 64 pages, 25 figs. Price 4s 6d.

In the preamble the measuring instruments are grouped into three classes: indicating instruments; value controlling instruments; and totalizing, aggregating or integrating instruments. This treatise is concerned chiefly with the two former. The points next considered are: variance of instruments; accuracy; sensitivity and passiveness; causes of variance; couplings in mechanisms; classification of couplings; point contacts and functional surfaces; examples of variance and examples of kinematically designed couplings.—Richard Rimbach.

Aircraft Instruments*

*Dr. W. G. Brombacher.***

AERONAUTIC instruments may be divided into two classes, flight instruments and ground instruments. Flight instruments include those installed in the aircraft and ground instruments those required on the ground in connection with aircraft operation. The dividing line between flight and ground instruments is very sharp. Flight instruments must be simple in construction and light in weight, must operate under difficult conditions, and must require absolutely the minimum amount of adjustments, etc., while in contrast, ground instruments may be as complicated and heavy as is necessary.

Flight instruments may be divided into service instruments and experimental instruments, although the dividing line between the two classes is not sharp. Service instruments include primarily, those which it is customary to install to aid the pilot in operating and navigating the aircraft. Experimental instruments are those used for performance testing in flight, for competitive flights, for free-flight investigations, new types of instruments not yet fully developed to the service stage, and instruments, which are not generally used. Experimental instruments include many types which will be in common use tomorrow. An important distinction exists between service and experimental instruments from the viewpoint of the instrument manufacturer, since service instruments in general are needed for every aircraft, while experimental instruments are required only to a limited extent by aircraft manufacturer.

Service instruments as defined also include those needed especially for high-altitude flying, and in aerial photography. At the present time these instruments may be designated as experimental, since relatively few are required at the present time.

CLASSIFICATION OF AIRCRAFT INSTRUMENTS

1	Power Plant Instruments	
	Service	
	Tachometers	
	Oil or water thermometer	
	Oil and fuel-pressure gages	
	Fuel-quantity gage	
	Fuel-flow meter	
		Experimental
		Supercharger instruments
		Recording tachometer
2	Speed Instruments	
	Service	
	Air-speed meter	
	True air-speed meter	
		Experimental
		Air-logs
		Air-speed recorders
		Ground-speed meter
3	Altitude Instruments	
	Service	
	Aneroid altimeter	
		Experimental
		Absolute altimeter
		Barograph
		Free-air thermometers
4	Navigation Instruments	
	Service	
	Magnetic compass	
	Turn indicator	
	Bank indicator	
	Drift indicator	
	Fore-and-aft inclinometers	
	Radio beacon	
	Clock	
		Experimental
		Sextant
		Chronometer or watch
		Induction compass

Aircraft instruments are particularly interdependent upon each other. Thus, a change from level flight to climbing will cause a decrease in air speed provided the engine speed remains constant, an increase in altitude,

*Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.
**Chief, Aeronautic Instruments Section, Bureau of Standards, Washington, D. C.

and a change in the indication of the for-and-aft inclinometer. Further, a rate-of-climb indicator is used now as an inclinometer rather than to measure rate of climb. It is therefore, with some reservation that the customary classification of service instruments is given. A number of experimental instruments under each class is included. Astronomical-navigation instruments are classed as experimental because their use is not common. They are needed only in experimental flying and in special long-distance flights.

POWER-PLANT INSTRUMENTS. At present supercharger instruments are classed as experimental, due to the fact that superchargers themselves are experimental. No serious problems are involved in furnishing the pressure gages and thermometers which may be needed to control the operation of the supercharger. Recording tachometers are useful in flight-test work, and as an aid in keeping an engine log. No recording tachometer of American make is commercially available at the present time. A detailed consideration of the service power-plant instruments follows.

Tachometers. At present the choice of a tachometer for single-engined airplanes is usually made between the chronometric and centrifugal-type instrument. These instruments are practically restricted to the case when a short drive shaft with few bends is possible. The essential features of these instruments have not changed in the last few years.[1] The performance of the chronometric instrument manufactured in this country has remained unchanged for many years. Except possibly for endurance, the performance is adequate.[1]

Centrifugal tachometers are now being made by a number of manufacturers in this country. A recent development in these instruments has been the reduction from a 3¾-in. to a 2¾-in. dial by the manufacturers at the initiation of the Navy Bureau of Aeronautics. Improvement of this type of instrument is still believed desirable, and no doubt will be effected in the near future.

The performance required of centrifugal tachometers by the military services is based on securing an accuracy of approximately 1% under all conditions. The instruments are subjected to the following tests:

a Test at room temperature for accuracy of calibration.
b Scale-error test at —35°C. and 45°C.
c Vibration for 3 hours and test to determine change in scale errors.
d Effect of over speed on scale errors.
e Effect on scale errors of accelerating to a given speed in one second for 500 times.
f Position error at various speeds.
g Change-in-scale errors after an endurance run of 300 hours.

The performance tolerances are most conveniently expressed for most of the type tests in terms of the average change in the error.

The direct-drive feature of centrifugal and chronometric tachometers is unsatisfactory in multi-engined ships where the distance from the cockpit to the engine is great. Current practice has been to mount the tachometer on a strut close to the out-board engine, thus forcing the pilot to turn from the instrument board in order to read the speed. Two of the possible types of instruments which permit an indication on the instrument board are now being developed by commercial organizations. One of these instruments consists of a commutator attached to the cam shaft of the engine, and an indicator consisting of an electromagnet and chronometric tachometer combined. A battery furnishes the power. The commutator controls

[1] G. E. Washburn, R. C. Sylvander and others, "Power Plant Instruments," N. A. C. A. Tech. Report No. 129, 1921.

the rate of operation of the electromagnet, which in turn operates a pawl forming the connecting link with the chronometric tachometer.

The other type of distant-indicating tachometer consists of the well-known direct-current magneto and voltmeter. Modifications are necessary however in order to make the instruments now available satisfactory for aircraft use. The bulk and weight of the magneto must be as small as possible, and the indicator should have a pointer motion greatly in excess of the customary 120 deg. in order to permit the use of an instrument of standard-case dimensions. A recent investigation in the Aeronautic Instruments Section of the Bureau of Standards conducted by J. B. Peterson has indicated the method by which complete compensation for the effect of temperature changes can be effected, and the extent to which this method can be used. It is essential to compensate the indicator and magneto separately since the temperature of each varies independently.

The importance of proper lubrication for tachometers should not be overlooked. If the instrument is to meet laboratory tests the lubricant should not freeze at—35°C., evaporate to any great extent at +45° C, nor require replacement during an endurance run of 300 hr. These conditions are not believed to be more severe than those obtained in service. Further experimentation on this point is desirable.

Aircraft Thermometer. These instruments are furnished in the vapor-pressure and the liquid-filled types. An accuracy of about 4°C is required of oil or water thermometers purchased under military specifications. This requirement causes no special difficulty to the manufacturer except for the effect of temperature on the line and indicator of liquid-filled instruments. Vapor-instruments on the other hand have the disadvantage of being affected by changes in altitude (pressure effect), and also of having roughly only one-sixth the operating pressure per degree centigrade at 0°C, as at 100°C. The vapor-pressure instrument appears on the whole to be the preferable type.

Oil-and Fuel-Pressure Gages. Since only a low degree of accuracy is required in measuring fuel and oil pressure (about 3% of the maximum indicated pressure) no development work has been necessary on the gages. There have been changes, such as the reduction of the dial size to $1\frac{7}{8}''$, and improvements in the method of connecting the tubing to the indicator. A further change may be desirable in the oil-pressure gage design in order to obviate the effect on the indication, of the oil freezing in the indicator and tubing at low temperatures.

Fuel-Quantity Gage. None of the variety of gages now available appears to give universal satisfaction. The instruments may be divided into the hydrostatic and float types. The indication of the hydrostatic-type instrument depends upon the density of the fuel as well as the head. The chief difficulty appears in securing a satisfactory instrument which indicates on the instrument board. In addition to the familiar aircraft and various automobile fuel gages available, two types may be classed as new developments, although not yet out of the experimental stage. In the first of these a pressure indicator at the instrument board is connected to the bottom and top of the tank by means of air lines. The line to the bottom of the tank is connected to a pressure capsule which is surrounded by the fuel so that its internal pressure is controlled by the hydrostatic head of the fuel thus affording a measure of the fuel quantity. A quantity of air remains in the

air-tight system which consists of the pressure element of the indicator, the air line, and the pressure capsule. The volume of the airtight system must be small, and the pressure capsule very flexible so that neither changes in air pressure nor temperature cause any change in the indication. A pressure capsule of cellophone has been found to meet the requirements if it can be kept free from contact with water.

The laboratory of a large electrical company has recently announced the successful development of a distant indicating instrument which depends on the effect of the pressure head of the liquid on a carbon pile. Attention is directed to two gages of the float type[2] which have met with some favor abroad.

Fuel-Flow Meters. A fuel-flow meter recently brought out commercially consists of a Venturi tube in the gas line, and an indicator on the instrument board. Two fuel lines lead from the Venturi tube to the indicator, one to a diaphragm capsule, and the other to the case of the instrument. This requires that the case be made airtight against a differential pressure of about 5 lb./in.^{2} For one type of Venturi tube now furnished, the differential pressure operating the indicator mechanism is about 16″ of water for a rate of flow of 60 gal./hour. Maintaining a leak-tight case under all conditions is problematical, so that it appears desirable to have cut-offs in the fuel lines to the case which can be controlled by the pilot. An indicator with two opposed diaphragm capsules would be a desirable development since it would make unnecessary the filling of the instrument case with the fuel.

SPEED INSTRUMENTS. Of the instruments classified as experimental, the air log is useful in the dead-reckoning method of position finding, and air-speed recorder in flight testing and flight research. The ground-speed meter is an example of an instrument which is desired for regular equipment, but none of the types now available are adequate since all depend upon the visibility of the ground for their operation.

Air-Speed Meter. The air speed of airplanes is usually determined from the differential pressure developed by tubes such as the pitot-static and pitot-venturi types. The indications of the differential-pressure type instruments depend on the air density as well as the air speed. The instruments are calibrated to indicate correctly at one air density. A correction must be applied to the indications for deviations from this density. The reading of the indicator, corrected for instrumental errors but uncorrected for deviations in air density, is called the indicated air speed.

Since 1920 steady progress has been made in changing from the pitot-venturi type to the pitot-static tube-type instrument. The adoption of the pitot-static type instrument has required the development of the technique of making diaphragm-pressure capsules for the measurement of low pressures. Today there is in use an indicator with a 2¾″ dial weighing 11 oz. in which the pointer has an angular movement of about 300 deg. for a pressure change as low as 10″ of water (equivalent to 140 m.p.h.). The performance of the indicator is determined by the following laboratory tests:

a Test at room temperature for scale errors.
b Scale-errors tests at —35°C. and +45°C.
c Vibrations for three hours and test to determine change in scale errors.
d Drift test or change in reading in five hours at a given (high) speed.
e Seasoning or effect on scale errors of subjecting instrument to 100 full-scale deflections.
f Position error at various readings.
g Effect on scale errors of subjecting instrument to specified over pressures.

C. J. Stewart, "Modern Developments in Aircraft Instruments," Journ. Roy. Aero. Soc., June 1928

Usually the smallest scale division is five miles/hour or five knots which makes the least reading at best 0.5 m.p.h. or knots. Scale errors up to 1.5% of the range are allowed. Average changes in calibration due to vibration, seasoning, and over-pressure have 0.5% tolerances, and a permitted drift 0.6% of the speed range. The change in scale value with temperature is somewhat larger, amounting in speed units to about 1 to 1.5% in the temperature interval —35°C. to +45°C. This is, as predicted by theory, about one-half of that caused by the change in the elastic modulus, but it can, of course, be much greater especially if the design is such that differential expansion is a factor.

The size of the pitot-static tube of the service-type air-speed meter is restricted because of the conditions involved in handling an airplane so that the openings are located in a position very close to the tube support. It is well known that the openings, especially the static openings, must be placed in the undisturbed air stream in order to develop the theoretically correct pressures. Finding the best location for a pitot-static tube with opening 4 or 6″ from a strut or 12″ in front of the leading edge of a wing is an individual problem for each type of aircraft. In nearly all cases it is necessary to calibrate the complete installation over a speed course in order to secure the accuracy in the air-speed measurement consistent with the present high quality of the indicating instrument. The errors in air-speed measurement in flight with the equipment usually installed are greatest at the stalling speeds. The simplest solution of the problem appears to be that of having available for the pilot's use, the results of a speed-course calibration of the air-speed meter installation, at least for the cruising and stalling speeds.

In the operation of the pitot-static air-speed meter consideration must be given to preventing stoppage of the line by rain, snow, and the freezing of rain. Trouble with leakage in the line is largely avoided by the present practice of using an all-metal tube, avoiding even the use of rubber connecting tubes.

True Air-Speed Indicators. By definition these are instruments which indicate the air speed directly, without the necessity of correcting for deviations of the air density from the standard value. In terms of true air speed the stalling speed of an airplane varies with air density, but in terms of indicated air speed it is independent of density. A knowledge of indicated air speed is therefore of primary importance in airplane operation. However, for the purposes of navigation it is also desirable to know the true air speed.

In airship operation a knowledge of the true air speed is desired since the operation of the ship does not, as in the case of airplanes, depend upon a knowledge of the indicated air speed. This is made necessary further by the difficulty of measuring small values of the indicated air speed. In order to mount the air-speed element in the undisturbed air stream it must be mounted well away from the airship which almost necessitates a distant indicating instrument of the electrical type. For use on Navy airships the Bureau of Standards has developed the commutator-condenser type of air-speed indicator. A propeller in the air stream operates a commutator through which an electric capacity is alternately charged from a battery and then discharged through an ammeter. The ammeter can be calibrated in terms of true air speed since the number of discharges per second is proportional to the true air speed. [3]

[3] F. L. Hunt, "New Types of Aircraft Instruments," Journ. Opt. Soc. of Am. p. 227, V 12, 1926

ALTITUDE INSTRUMENTS. Of the altitude instruments called experimental in this paper the absolute altimeter will undoubtedly be a future service instrument. Three possible methods of measuring the tape-line altitude of the aircraft, as contrasted with the pressure altitude, have been under intensive development in a number of laboratories both here and abroad. These methods have given rise to the following instruments: the sonic altimeter, the capacity altimeter, and the radio altimeter. No detailed description of the individual instruments thus far developed is available, but it appears at the present writing that absolute altimeters of one or more of these types will soon be available.

The barograph and free-air thermometer included under experimental instruments are largely used in the flight testing of aircraft and in special investigations and flights. Their consideration is beyond the scope of this paper.

Aneroid Altimeter. The service altimeter of today varies greatly in external appearance and performance from its predecessor of 10 years ago. The mechanism is now enclosed in a bakelite case, the dial size has been reduced from $3\frac{1}{2}$ to $2\frac{3}{4}$" and the weight from 14 to 11 oz. The ranges of the instruments commonly used by the military services are now 20,000 and 35,000 ft. with a pointer movement of two revolutions for the 20,000 ft. instrument, and $1\frac{3}{4}$ revolutions for the higher-range instrument. The older instruments are based on a pointer movement of one revolution for 20,000 ft. The scales of the instruments are equally divided, as has always been customary in this country.

The improvement of the elastic qualities of the altimeter has opened up a number of possibilities, among which may be mentioned its increased utility for landing purposes. If an instrument of good quality and with known errors is used, it is believed that the overall instrumental performance can be depended upon to within 50 ft., even under severe conditions of usage. In order to avoid the inherent defects of the barometric method of measuring altitude, the effective use of the instrument is linked up with obtaining information from the proposed landing field as to the pressure of the ground level so that the pointer of the altimeter may be reset in such a way that it will indicate zero upon landing.

One of the problems of aerial photography is that of flying level. Methods have been proposed involving the use of a statoscope, a rate-of-climb indicator or a sensitive altimeter, as well as methods of a more indirect nature. The present trend of development in altimeters indicates that the use of a sensitive altimeter may be the ultimate solution. Instrument makers are making effective progress at the present time in the development of an altimeter of 20,000 ft. range with the pointer making 20 revolutions for this range. One manufacturer now has available an instrument of this type with a 6" dial and another an instrument with a $2\frac{3}{4}$" dial and two concentric pointers. Further developments are under way and will be looked forward to with interest.

NAVIGATION INSTRUMENTS. The navigation of an airplane consists principally in maintaining the normal flying attitude and the proper direction of flight toward the destination, and in being able to determine the position of the airplane and to clear obstacles. In scheduled flights over airways, and in a large amount of other flying when the ground is visible, the navigation is of the simplest sort. The navigator determines his

position and flying attitude almost entirely by observing landmarks. These are observed to give the position, and are used also to determine the direction of flight. The present movement to have the names of towns, together with the direction of the meridian and location of nearest landing field, marked on roofs and other suitable spots is a great aid to this type of navigation. The service type of navigation instruments listed in this paper are useful but not essential under these conditions.

An entirely different situation exists when the ground is not visible. Three elements must be considered, maintaining the proper flying attitude, the proper direction of flight, and making the landing. The proper flying attitude can be maintained only by the aid of instruments, of which all of those needed are now available.

The magnetic compass and the turn indicator are inadequate to maintain the proper course in flight under these conditions, since the drift cannot be measured when the ground is invisible. The radio beacon has been developed to meet this problem and has been found to be indispensable in flights which are made during poor visibility.

The most recent work on the improvement of navigation during poor visibility has been in devising methods for making a successful landing. To do this the navigator needs to locate the landing field, and know his absolute altitude above it. The progress in developing absolute altimeters has been discussed. Progress has been made in the method of locating the landing field based on a property of the radio beacon. Although a considerable amount of development work is still essential in order to make landings during fog a common operation, it appears that promising methods for doing so have been found.

Aerial navigation by astronomical methods is commonly employed only in flights over oceans, and in long flights over undeveloped or unfamiliar country. The necessity for their use is becoming less and less as the operation of the radio beacon is extended to cover more and more air lines. The astronomical method of position finding, has an inherent advantage over other methods in that it is independent of all ground equipment, for which reason its use will always continue in many cases. Important improvements are being made in the method of position finding by astronomical methods. The sextant and time pieces have been improved, as well as the methods of computing.[4,5]

Magnetic Compass. There has been a slow and steady improvement in the performance of magnetic compasses. The important features of design are:

a Adequate provision for the expansion of the damping liquid due to temperature, and at the same time providing for the effect of low pressure.
b The reduction of the weight of the compass card consistent with securing adequate damping.
c Use of better magnet steels as these become available. Colbat magnet steels are now being used, from which relatively stronger magnets per unit volume can be produced.
d The selection of the proper damping liquid. For some years mineral spirits or varnolene has been used as the damping liquid. A recent study by Keulegan[6] of damping liquids from the viewpoint of their use in aircraft instruments may make possible greater latitude in the selection of the liquid.

The chief difficulty with compasses at the present time is that associated with their installation in the aircraft. The effect of vibration and the effect of extraneous magnetic fields produced in the aircraft combine to make proper installation a comparatively difficult matter in many cases. The

[4] P. V. H. Weems, "Line of Position Book," U. S. Naval Inst., 1928.
[5] Navy Hydrographic office publication No. 208.
[6] G. H. Keulegan, "Investigation of Damping Liquids for Aircraft Instruments," N. A. C. A. Tech, Report No. 299, 1929.

effect of vibration is being minimized by the use of vibration-absorbing mountings. No general solution for the effect of the extraneous magnetic fields has been found save that of changing the location of the compass. The compass must be compensated after installation against the effect of the magnetized parts of the ship, and for the deviation.[7]

Compasses of new design are subjected to the following laboratory test:

a The instrument is subjected to a pressure corresponding to the highest altitude at which it will be used in order to determine the effect on the expansion chamber, and to note generally possible injurious effects of low pressure.

b The instrument is subjected to a temperature of —35°C. The liquid should not freeze at this temperature.

c The critical test for the adequacy of the expansion chamber is to subject the instrument to a temperature of +45°C. There should be no leaks at this temperature,nor should a bubble form in the compass bowl upon reducing the temperature.

d The period of the compass is determined at +20°C. The procedure usually consists in deflecting the compass card 45 deg. than allowing it to swing freely. While swinging the time interval is obtained for the card to swing through the zero position for the first time and second time. Twice this time is the period. In order to be of any value these data must be obtained when the compass is in a horizontal magnetic field of standard strength (0.180 gauss). This magnetic field is practically never found inside of a building unless specially constructed with this end in view, so that recourse must usually be had to a suitable location out of doors. The period should be obtained at low temperature, but it is difficult to control both the external magnetic field and the temperature simultaneously. Qualitative data of some value may be obtained on this point in the low-temperature test above mentioned.

e Current specifications also give tolerances for the card error, balance of card, friction error, heeling, and levelling.

Although an experimental instrument, the induction compass should be mentioned. It may also be called a distant indicating compass since the chief advantage of this instrument is that its magnetic element may be placed in the most favorable part of the aircraft as regards freedom from magnetic disturbances. Since the announcement by Heyl and Briggs of the first working model in January, 1922, development work has been continuously in progress. Only one type, the Pioneer compass, is at present available commercially. Other types are being worked on experimentally which may lead to improved instruments. The improvements will consist of reduction in weight, improved reliability and perhaps a reduction in cost. The induction compass is at present classed as an experimental instrument because it is not generally used, which is largely due to its relatively higher cost and its present lack of reliability as compared with the magnetic compass. Its ultimate adoption as a service instrument is sure.

Turn Indicator. New developments in the gyroscopic turn indicator have been largely along the lines of a general expansion of its use rather than along its further mechanical development. The wind-driven instrument giving qualitative indications has been available in substantially the same design for a number of years, and has usually given satisfactory service.[8]

Tests show that when properly lubricated with a low pourpoint oil, the starting pressure and friction characteristics of the instrument are substantially the same in the temperature range —35°C to +45°C.

There is some difference of opinion on the part of pilots and navigators as to the proper sensitivity of the turn indicator. Military specifications requires a deflection of $\frac{1}{16}''$ in turning at a rate of 36 deg./min., $\frac{3}{8}''$ for 360 deg./min., and $\frac{3}{4}''$ for 1080 deg.; min., when the instrument is operating under a suction of 26″ of water. This suction is developed only at one speed of the aircraft, so that the sensitivity of the instrument will in general be different from the above. The instruments, however, are provided with

7 M. F. Schoeffel, "The Installation and Correction of Compasses in Airplanes," N. A. C. A. Tech. Note No. 262, 1927.

8 T. C. Lonnquest, "Use and Maintenance of Turn Indicators," Bur. of Aero. Tech. Note No. 184, 1928.

an adjustment for the sensitivity, and also for damping so that these within limits can be adjusted as desired.

Bank Indicator. A curved-glass tube containing a steel ball, and filled with a suitable liquid for damping purposes is used as the bank indicator, and in the absence of turns, to indicate rolling. Until quite recently a $\frac{1}{4}$" ball has been used, but in the opinion of pilots this size of ball is too small. At the present time standardization appears to be taking place around the use of a steel ball $\frac{7}{16}$" in diameter. Proper damping is the controlling factor in a proper design. A satisfactory performance is determined by the results of two tests, vibration and time of roll at low temperature. If the viscosity of the damping liquid is inadequate at room temperature the ball spins when subjected to vibration, and in general will climb up the tube. Liquids which give entirely adequate damping at room temperatures will either be found to be frozen or so viscous as to be unsuitable when the inclinometer is cooled to—35°C. Preliminary experiments indicate that satisfactory low-temperature performance can be obtained with certain solutions having a viscosity as high as 0.04 poise at 25°C., which value is sufficient to damp out the effects of a vibration of an amplitude of approximately $\frac{1}{32}$". It is obvious, of course, that the performance of the inclinometer also depends upon the clearance between the ball and tube. If the inclinometer is designed to have a small clearance between the ball and tube, the cost of the instruments will be relatively great owing to the difficulty of obtaining glass tubing with a uniform bore. Tests show unexpectedly that better damping is secured by having relatively large clearances between the ball and tube.[6]

Drift Indicators. The measurement of drift can at present be made only when the ground is visible. The methods used have not varied essentially in the past few years. There has been, however, a tendency toward more simple apparatus.

As is well known[9] the wind and ground speed of the aircraft can be determined from drift measurements if the true air speed be known. Further, the drift indicators commonly available contain suitable sights which with a stop watch, and a knowledge of the altitude, also determine the ground speed. However, the common practice is to dispense with the possibility of determining wind and ground speed.

The proper heading only is determined. This is done by measuring the drift when on a compass course, adjusting the heading by the amount of the drift, and then repeating the process until on the proper course. When over water or flying at night smoke bombs or flares are used to furnish the object upon which to sight.

Fore-and-Aft Inclinometers. The instruments which may be termed fore-and-aft inclinometers are not strictly service instruments since their use is not common. Two types of instruments are available, one a liquid-in-glass type and the other a combined pendulum and gyro instrument. The first-named instrument is affected alike by inclination, and fore-and-aft accelerations, The pendulum-gyro type instrument gives indications which are practically independent of the fore-and-aft acceleration. The indication of both instruments is affected by the angle of attack.

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[9] H. N. Eaton, "Aerial Navigation and Navigating Instruments," N. A. C. A. Tech Report No. 131, 1921.

Experience with the capillary-leak-tube type indicator has shown the instrument to be of little use in indicating the rate of climb accurately. It has been further found, however, that the instrument indicates qualitatively the fore-and-aft inclination. The instrument is free from the acceleration and angle of attack errors above mentioned. The indication depends on the rate of change of pressure.

A change in indication of the air-speed indicator associated with a constant speed of the propeller is also often used to indicate fore-and-aft inclination.

Radio Beacon. A discussion of the radio beacon is out of place in this place except as regards its function as an aid to navigation. The chief use of the radio beacon is in flying during poor visibility and fog. It enables the proper direction toward the destination to be maintained. Without the radio beacon the direction of flight would have to be determined by means of the magnetic compass, a method which is unsatisfactory because of the impossibility of determining the drift, and correcting the heading for it. A further property of the radio beacon is now in the process of being utilized. When the airplane is equipped with a vertical-rod antenna, a drop in the strength of the signal received on the airplane occurs when directly over the beacon. This phenomenon gives a method of locating the landing field. The radio beacon is essential in fog flying since no other successful methods have been developed to maintain proper direction and to locate the landing field.

To celebrate an addition to their plant, which in the last year has doubled in size, and to welcome new members of their organization, which during the same period has grown from 750 to 1150, employees of the Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, Pa., held a minstrel show and dance in the ballroom of the Elks Club on Friday evening, December 13th, despite the traditional superstition associated with that date.

During the evening it was pointed out that the latest addition to the Leeds & Northrup Company plant increased the floor space from about two to over four acres. This is the largest of a series of additions to the original building, which was erected in 1903, shortly after the organization of the company. These previous extensions took place in 1906, 1918, 1925 and 1927. The 1929 extension takes in the entire neighboring plant formerly occupied by the Atwater Kent Manufacturing Company.

The expansion of the Leeds & Northrup Company has been progressive and is viewed largely as a reflection of the growing interest shown by industry in precision instruments for the control of industrial processes. This interest has called for the increasing use of L. & N. products such as Potentiometer Pyromotors for controlling, indicating or recording industrial process temperatures, Hump and Homo Heat Treating Furnaces, Combustion Control Apparatus and precision scientific instruments.

Developments in Laboratory Apparatus During 1929

*Arthur Schroder**

THE year 1929 has witnessed the culmination of several years of intensive research and development work on new laboratory equipment, designed for greater accuracy of measurement of the various properties of matter. Due to limited space available, this article will treat only of the more prominent developments, since these are typical of the progressive American attitude toward the design of instruments of great manipulative convenience combined with great precision.

One of the outstanding developments within the year is the Universal Spectro-Photometric Outfit perfected by the Bausch & Lomb Optical Company. This outfit consists of their No. 2700 Spectrometer and a new Polarization Photometer[1], so mounted on a universal stand that all types of spectrographic determinations can be made with the one apparatus. The successive portions of the spectrum generated can be measured and from these, complete density or transmission curves plotted. Transmission measurements on transparent solids and liquids, and reflection measurements on opaque materials can all be made.

The new polarization photometer, modified Marten's type, can also be used with this outfit. This combination can be used for the analysis of structure, composition and purity of chemical compounds, dyes, etc., light transmissive properties of protective glasses, photometric and photographic filters, analyses of body fluids, and the study of visibility and hue sensations in psycho-physical optics.

A new chemical microscope, (Fig. 1) designed by Professor Chamont of the Cornell University, a new research microscope (Fig. 2) of radically different design, and which is about to be announced as this goes to press, a new micro-metallograph (Fig. 3) of simplified construction and a new all-metal quartz spectrograph (Fig. 4) have all been developed by the Bausch & Lomb Optical Company during this last year.

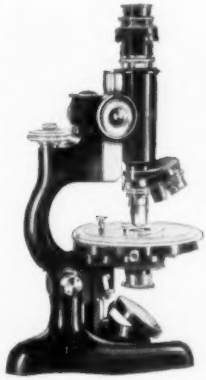

Fig. 1—New Chemical Microscope by Prof. Chamot, Bausch and Lomb

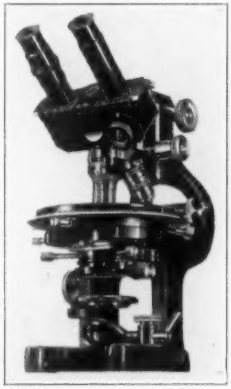

Fig. 2—New B & L Research Microscope

The all-metal quartz spectrograph, manufactured by the Gaertner Scientific Corporation, was described[2] in an earlier number of INSTRUMENTS.

*Director of Technical Service, Fisher Scientific Company.
[1]INSTRUMENTS, July 1929, page 245
[2]INSTRUMENTS, October 1929, page 362.

A new wavelength spectrometer, (Fig. 5) with a wavelength dial instead of the conventional drum, was also developed by this last company.

The year 1929 has also seen the introduction of a new method for the measurement of color and turbidity of solutions, called "Scopometry"[3]. The method and apparatus (called Scopometer, see Fig. 4, Recent Advances

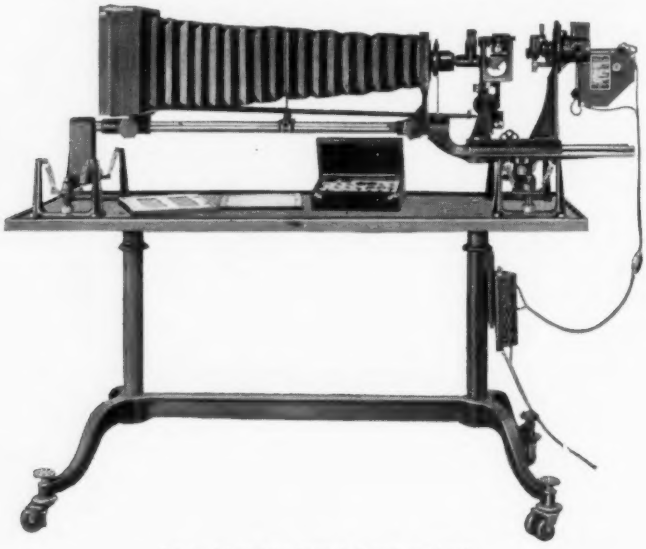

Fig. 3—Micro-Metallograph, Bausch and Lomb

in Colorimetry by Dr. Foster Dee Snell in this issue) have been developed by Dr. W. G. Exton of the laboratories of the Prudential Insurance Company in conjunction with the Technical Staff of the Bausch & Lomb Optical Company. The criterion used is the disappearance of an illuminated target against a field of lower intensity, and is effected by adding to the density of the sample under test, a second density derived from a neutral wedge of varying degrees of density. The technique is the same for both colored and turbid solutions. The method has the advantages of speed and the absence of necessity for maintaining standard solutions. The accuracy of the Scopometer is within that required in routine chemical diagnostic work.

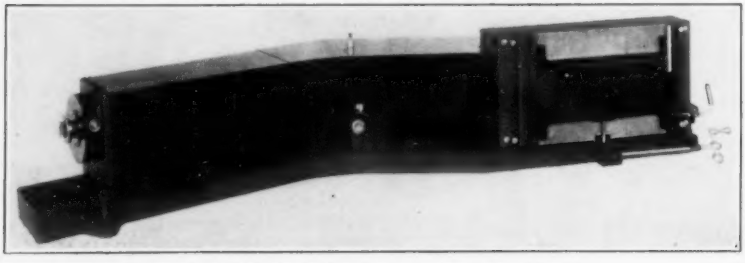

Fig. 4—All-Metal Quartz Spectrograph, Bausch and Lomb.

[3]For a review of the science of color and turbidity measurement see Yoe and Kleinmann, "Photometric Chemical Analysis," John Wiley & Sons, 1928-29.

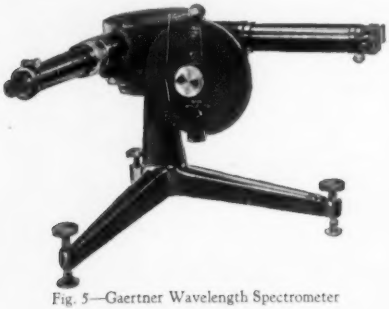

Fig. 5—Gaertner Wavelength Spectrometer

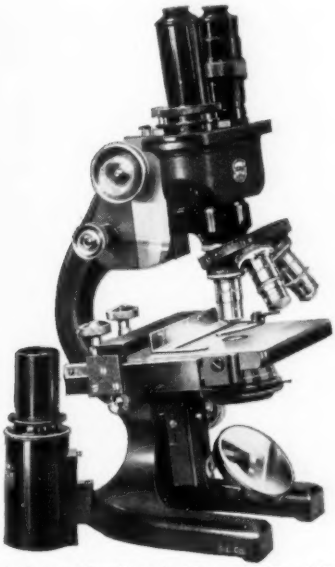

Fig. 6—Spencer New Binocular Microscope No. 4 MH

A new series of binocular microscopes, (Fig. 6) with new types of objectives and oculars of higher magnification and larger fields than hitherto, and a new series of more accurate and wider range microtomes have been brought out by the Spencer Lens Company.

The science of weighing has also received its share of attention. A new keyboard analytical balance[4] with an all-aluminum frame, (Fig. 7) with weights applied by tapping keys similar to those on a typewriter, and a new micro-analytical balance,[5] (Fig. 8) with a capacity of 25 grams and sensitive to .001 milligrams (.000001 gms), have been sponsored by the Fisher Scientific Company. The direct reading gravitometer for use in rubber laboratories has been described[6] in a previous issue. The Welch Manufacturing Company has marketed an improved line of multiple beam, trip balances of wide range.

Fig. 7

In the realm of time measurement, new tape recording, two pen chronographs (Fig. 9) of great accuracy and wide range of recorded time interval, have been de-

[4] "The Laboratory," Vol. 1, No. 4, page 64 (1928) also Vol. 2, No. 5, page 69 (1929).
[5] "The Laboratory," Vol. 2, No. 4, page 54 (1929)
[6] INSTRUMENTS, July 1929, page 259

veloped by the Gaertner Scientific Corporation. This Corporation is also about to announce a new printing chronograph, similar to that of the late Professor Hough of the Dearborn Observatory of Northwestern University, but differing somewhat in the method employed for controlling the speed and assuring an accuracy of one one-hundredth of a second. Details of the design and construction of this chronograph are given in this issue of INSTRUMENTS.

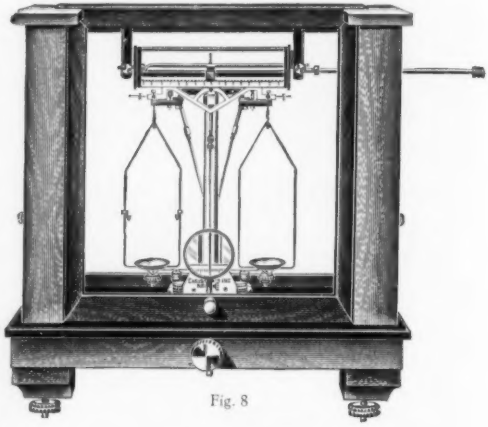

Fig. 8

Viscosity measurements have been simplified by the use of the "Auto-Constant Temperature Viscosimeter[7]," which conforms to the A.S.T.M. Specifications (both Universal and Furol).

In the field of more general laboratory apparatus, a new drying oven and improved electric extraction apparatus have been marketed by the E. H. Sargent Company, while the Welch Mfg. Company has developed a new line of Wegner high speed, high vacuum pumps, a series of non-inductive rheostats, and improved their general line of physical apparatus for school use.

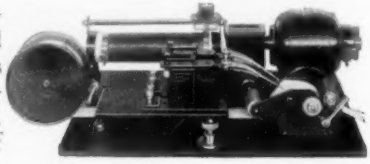

Fig. 9—Two-Pen Recording Chronograph (Gaertner)

It has been interesting to note the trend of the times as typified by the developments in laboratory apparatus during the year just closing. The manufacturers of scientific instruments in America are continuously developing new instruments, and are making America independent of foreign sources of supplies. May the fine work done by the manufacturers of optical apparatus and balances serve as a spur to manufacturers of other equipment, and urge them on toward greater achievement.

Due recognition should be given the newly arrived, but rapidly growing, Analytical Edition of the Journal of Industrial and Engineering Chemistry, published by the American Chemical Society. This magazine now only one year old, has already made a place for itself among the annuals of literature on methods of chemical analysis and the instruments involved. Its pages are replete with designs, specifications and descriptions of many new instruments which show promise of being the future standards of measurement. We have welcomed it most heartily and wish its future will crown it with increasing successes.

The development of scientific instruments and apparatus in America has been going on at a rapid pace for the last ten years. We believe, from the international interest recently shown in American instruments, that 1929 will be referred to as the first year in which American leadership in this field was generally recognized.

[7] "The Laboratory," Vol. 2, No. 4, page 52 (1929)

Electrical Instrument Development During 1929

*E. S. Lincoln**

The development of electrical measuring instruments during the past year has shown a tendency of refinement with no radical departures from products in previous years. A greater accuracy, compactness, and an increase in the variety of electrical measuring instruments and many improvements in instruments using electricity as a means of measuring have been noticed. The growth of the radio business is increasing the demand for measuring instruments, especially in the form of testing sets, low reading instruments.

The instruments of today are based upon principles discovered in the early part of the eighteenth century and there appears to be no likelihood of radical changes for sometime to come.

Until some new principle is discovered upon which electrical measuring instruments will be made the industry will continue these refinements of details which will lead to greater perfection.

All manufacturers have devoted their energies to the improvement of instruments already on the market and have not attempted to bring out any new lines at this time. Some of these have also brought out additional instruments a number of which are as follows:

The Weston Electrical Instrument Corporation have placed upon the market some instruments which are of great interest to the radio industry. Among these is model 526 Direct Reading Radio Tube Tester. This is a very compact portable outfit, which is very complete as will be seen by referring to Figure 1. This set is designed for production testing of radio tubes.

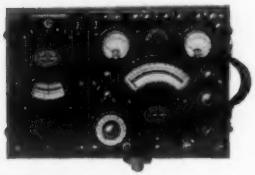

Fig. 1

This same Company has also developed a testing set for servicing radio apparatus, known as model 547. This is also a portable outfit and intended for the use of the servicing requirements of retail dealers. This set is mentioned in detail on page 311 of the September 1929 issue.

Another instrument that will be of interest to all radio users is the model 506 Resistance Meter. This is a 2″ round flush type meter which will measure resistance from 10 to 10,000 ohms and is direct reading. It can be operated by two flash light cells making it a very inexpensive and convenient outfit for resistance measurements.

They have also developed a Portable Precision Triple D. C. Voltameter, known as model 540. This is a very compact outfit weighing less than two pounds and having a sensitivity of 100 ohms per volt. It is especially adapted for railway signal servicing and testing.

The General Electric Company have brought out a very compact line of rectangular switchboard instruments for both A. C. and D. C. service.

This same Company has also developed a small size round type of switchboard instrument for use on both A. C. and D. C. systems. In order to

*Consulting Electrical Engineer, New York, N. Y

obtain a small size instrument for use in making measurements on low voltage A. C. circuits a full wave copper oxide rectifier has been placed inside of a small permanent-magnet moving-coil instrument. These rectifiers make it possible to use the instrument on an alternating current circuit and have the advantage of high sensitivity and low power consumption characteristics of D. C. measuring instruments. By this method it is possible to make these small sized instruments with an accuracy of 3% and having a scale as low as three volts. Such instruments have a resistance as high as 4000 ohms per volt. High resistance milliammeters are also available in these small sizes, which measure from two to three inches in diameter. The copper oxide rectifiers used in these instruments have excellent permanency characteristics which insure and maintain accuracy of the instrument indefinitely. Frequency errors are negligible over a range of 25 to 1000 cycles and even with frequencies as high as 6000 cycles the errors are small.

This company has also developed a high resistance volt meter for use on both A. C. and D. C. circuits. The instrument is of the permanent-magnet moving-coil type and is used as such for direct current measurements. For A. C. measurements the copper oxide rectifier is placed in circuits by means of a special switch mounted on the instrument base. This particular instrument is known as type DW-2X. It is very compact and has a resistance of 750 ohms per volt.

The General Electric Company has also devoted considerable time to the development and improvement in portable graphic instruments and have a very complete line for both A. C. and D. C. service. Many of these developments and improvements have been completed during the past year.

The Roller-Smith Company has developed a complete line of rectangular instruments covering both A. C. and D. C. types.

This same Company has also developed a testing instrument for the radio industry known as Radio Continuity Tester, illustrated on page 221 of the June issue. This instrument is provided with a chart showing how to make tests on all the different radio circuits. The method used is very practicable and certain indications on the scale of the instrument refer to numbers from which the user may determine the difficulty in the set.

In the August issue, page 274, a set of small sized portable instruments were described having been placed upon the market by the Westinghouse Electric Manufacturing Company. These instruments fit in a special case making them well adapted for testing work outside of a laboratory.

This same Company has devoted considerable time to refinements of the watthour meters. Details of these refinements were described on page 141, of the April 1929 issue.

The Jewell Electrical Instrument Company have developed two instuments of interest to the radio industry. The first is a Radio Set Analyzer for testing screen grid tubes. This outfit was orginally designed for 1928 but has been redesigned to make its use more extensive.

A description of this set will be found on page 287 of the August 1929 issue.

This same Company has also developed a portable Direct Reading Tube Tester which is known as pattern 216. This instrument is described on page 290 of the August issue.

A rectangular type of graphic instrument, having a round chart, has been developed by the Bristol Company. While no new principles are involved, this particular instrument on account of its compactness and shape make it

well adapted for switchboard use. A complete description of this instrument will be found on page 315 of the September issue.

Many developments have been made in the field of measuring instruments for measuring non-electrical quantities but using electricity as a means. One of these instruments, which is of considerable interest, is the Esterline-Angus Straight Line Thickness Recorder. This instrument is designed to give a continuous record of the thickness of such material as cardboard, sheet metal, tire fabric, insulating material, etc. This is an electrical instrument and differs from the mechanical instrument inasmuch as the recording apparatus can be placed at practically any distance from the measuring gauge. This instrument will be described in detail in a future issue and should be of considerable interest to manufacturers of sheet material where uniform thickness is of importance.

Leeds & Northrup Company have made a number of new and interesting additions to their line of temperature measuring instruments during the past year, which are covered in this issue in an article by M. F. Béhar entitled "Temperature Instrument Developments in 1929."

The Weston Electrical Instrument Corporation have placed upon the market a heat flow meter known as model 553. This instrument makes it possible to measure accurately the loss of heat in pipe lines, etc. This instrument is described in detail in this issue.

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The Effects of Errors in Surveying. Henry Briggs. 1912. Cloth, 179 pages, $4.00.
Treatise on Mine Surveying. Bennett Brough and H. Dean. 1926. Cloth, 473 pages, $5.50.
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Practical Pyrometry. Erwin S. Ferry and Others. 1917. Cloth, 147 pages $1.50.
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Modern Gaging Practice. A. Dowd and F. Curtis. 1925. Cloth, 280 pages, $3.00.
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Metallurgical Analysis. N. Lord and D. Demorest. 1924. Cloth, 474 pages, $4.00.
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Technical Analysis of Steel and Steel Works Materials. F. Sisco. 1923. Cloth, 543 pages, $5.00.
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Laboratory Manual of Testing Materials. W. Hatt and H. Scofield. 1926. Cloth, 166 pages, $2.00.
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Light, Photometry and Illuminating Engineering. W. Barrows, 1925. Cloth, 412 pages, $4.00.
Electrical Photometry and Illumination. Hermann Bohle. 1925. Cloth, 427 pages, $11.00.
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A Handbook of Physics Measurements. Erwin S. Ferry and others. Vol. I. Fundamental Measurements, properties of matter and optics. 1926. 288 pages. $2.50. Vol. II. Vibratory Motion, Sound, Heat, Electricity and Magnetism. 1926. Cloth, 235 pages, $2.00.
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The Engineer's Handbook of Industrial Instruments

M. F. Béhar*

INTRODUCTION

Dozens of useful engineering handbooks contain references to instruments—but most of these references are brief, and all are necessarily limited in scope and treatment by the special field covered by each handbook. . . . Scores of excellent scientific treatises deal partly with instruments—but only from the scientific viewpoint. . . . Hundreds of informative catalogues of industrial instruments go into details—but their main purpose is to promote sales.

In one respect this book is a compilation—the first of its kind—with all available engineering, scientific and sales literature as sources. It combines a digest of engineering references, a summary of scientific principles and a "condensed general catalogue" of all modern industrial instruments that have won acceptance in American industries. Thus there are few original photographs or diagrams.

In another sense it is a new and much-needed text-book—also the first of its kind—with a systematic progression of subjects so treated that it may be studied. Thus most of its text matter is original—especially written by the author. In addition, several specialists have contributed portions of important chapters, thus enhancing its value far beyond that of the possible production of one man in this era of specialization.

But above all this is a Handbook—a manual or reference work planned and designed for practical use as a tool by practical men in industry—exactly as its title signifies. Thus the arrangement into chapters and the divisions of each chapter, while they may shock some scientists, will serve the purposes of the busy engineer and of the ambitious student. This Handbook, in short, is primarily designed to fill a real and great need as a new tool of industry.

This Handbook also fills broad gaps between (and lesser gaps in) existent special works. A power plant specialist, for example, will find no information on boiler test procedure, but he will find more detailed information on temperature and pressure instruments, on ways to economize process steam, etc., than can logically be included in power-plant testing manuals.

A chemical engineer will find no discussions of the reactions involved in processes, but he will find the most complete body of data on the measurement and control of processing conditions ever assembled into one book.

The production man, whatever be his official title and whatever branch of engineering he may practice, is the one for whose particular benefit this Handbook is written. It had to be so, for the very purpose of industrial instruments is to aid production, to subserve the application of efficiency principles, "the One Best Way," "highest quality at lowest production cost," and the other maxims of scientific management.

Controversial subjects are avoided. There are enough important facts about industrial instruments—well-known facts and facts that deserve to be better known—to fill a book several times the length of this Handbook.

*Engineering Editor.

Space has been alloted, as far as is humanly possible, on a statistical basis and (we repeat) with the needs of the practical man in mind—not those of the scientific student. In determining the wordage and the illustration area for each group, class or type, consideration was given to the probable number of engineers to whom each would be of interest, to the estimated number of the instruments in actual industrial use, and to the known industrial importance of their uses. For similar reasons no space at all was assigned to devices, mechanisms and apparatus not classifiable as *industrial* instruments . . . What *are* industrial instruments?

There is no definite answer. The question is nevertheless an interesting one and is therefore discussed in the first chapter—not in an authoritative way but from the personal viewpoint of the author . . . What, then, of the author?

Suffice it to mention that the author has loved instruments all his life, has designed instruments, has built instruments with his hands, has earned a living by writing about instruments and now, as engineering editor of INSTRUMENTS, enjoys obvious facilities for thoroughly completing such a handbook as the present one. To him the preparation of this Handbook was a pleasure. To the user may it prove a convenience. Whereas the author often prolonged far into the night the pleasure of writing it, may the user find *his* pleasure in the time saved through its use? And whereas the author found added zest in life in preparing it as a labor of love, may the user find *his* added zest in the dollar-and-cent profits effected through extended applications of industrial instruments.

CHAPTER I

GENERAL DISCUSSION AND DEFINITIONS

What are industrial instruments? It is easier to define them by saying that they are not surveying, astronomical, navigation or surgical instruments. Nor are the instruments dealt with in this book capable of being classed as laboratory or scientific instruments. No official definition of industrial instruments has been issued by authoritative governmental, professional or manufacturing bodies, and therefore the scope of this book had to be arbitrary. It treats only of "practical" instruments—of instruments relating to definite (a) processing, working and storage conditions, (b) physical and chemical properties and (c) compositions, proportionings and analyses. But the author's own lists of (a) conditions, (b) properties and (c) examples of proportioning and analysis, include only those for which "industrial" instruments are applicable. Which is like defining gravity as the attraction of matter and matter as that which is acted on by gravity, but it cannot be helped. Besides, a practical definition of industrial instruments will make itself understood in this first chapter.

The outstanding characteristic of industrial instruments is that they yield tangible and practical dividends, determinable in dollars and cents, which dividends write off the original cost in a very small number of years—sometimes in a small number of weeks. As one manufacturer puts it, they are the "sixth sense of industry." Another manufacturer calls his line of instruments "the compass of industry." A third makes use of such expressions as "every industry is a temperature industry," and is proud to designate his plant as "temperature headquarters." A fourth emphasizes the dictum of Pascal "To measure is to economize." Still another refers to his instruments as "investments." These slogans are based on reality.

The devices described in this handbook, taken as a general category, are not bought as ornaments, but they are acquired as investments, because they render some or all of the following services to industry:

1. Labor saving
2. Fuel saving
3. Increased production
4. Better quality of product
5. Elimination of "rejects"
6. Uniformity
7. Minimizing reliance on human watchfulness
8. Accident prevention

Each of the items on the above list is stated in a brief and broad form; and each will be amplified and demonstrated. The list, moreover, while it helps to define industrial instruments by summarizing the reasons for which they are bought, might be applied to other devices. For example, the flyball governor invented by James Watt might be called an industrial instrument. As a matter of fact, where is nothing in the foregoing portion of our definition to preclude calling an engine governor an industrial instrument. We therefore must lay down another arbitrary distinction:

All devices known as regulators, controllers or governors incorporated in engines, turbines, generators and other prime movers have been excluded from this Handbook—for several valid reasons. An elucidatory statement of these reasons is not out of place for it is needed to eliminate a source of confusion. These devices constitute essential parts of the machines; they are conceived, designed, built, sold, installed and maintained *with* the machines; they *belong* to the machines and cannot conveniently be studied separately; they seldom can function on other machines; they are not readily classifiable (except into such broad types as "fly-wheel governors," "ball governors," etc.); and finally, their design is not—to the author's knowledge—a specialized science, nor their application a specialized branch of engineering, nor their manufacture a specialized industry. The author desires to stress the point that automatic regulation of processing conditions is now recognized as a science, that the proper application of standardized industrial instruments to improve products and effect economies is a branch of engineering, and that the manufacture of standardized industrial instruments, by several hundred firms in the United States alone, amounts to an industry of importance, as to size as well as to usefulness.

Another important characteristic of industrial instruments is that they are definite means of attaining definite ends. From the viewpoint of the industrial engineer, the application of an instrument is of far greater importance than the instrument itself. Proper installation counts more than intrinsic accuracy. The usefulness of instruments depends on proper appreciation of their uses. Let us therefore classify these uses:

Processing Conditions. We are living in a civilization based on industrial processes. Everything that we wear, nearly everything that we use, and most of what we eat, has been processed. Some processes are traceable to ancient origins; others are offshoots of modern discoveries in the field of pure science, but all have a common characteristic: as they are taken from the research laboratory to the commercial plant they are industrialized. That is to say, they are carried on in standardized production equipment and a determined attempt is made to reduce variables in order to prevent accidents and spoilage and to assure "highest quality of output at lowest

production cost." This is Frederick Taylor's familiar "One Best Way" for which all technicians strive. In processing, this "One Best Way" needs further definition. The industrial engineers' bread-and-butter problem is to assure that the process over which he has charge will be not only successful when he is personally watching over it but *reproducibly successful.* He must conquer the variables. The "One Best Way" is to him but a vague ideal. With this in mind the author several years ago pointed out that some of the "forces of Nature" or "variables" with which the engineer is immediately concerned can be expressed as *Measurable Conditions* and he postulated the following law:

"*For Every Process There is One Best Set of Conditions.*"

Reference is purposely made to measurable conditions*. In their probable order of importance, these are as follows:

1. Temperature
2. Humidity
3. Pressure (or Vacuum)
4. Liquid Level
5. Flow
6. Duration or Timing (of operation or process)
7. Rate or Speed (of mechanical parts)
8. Voltage, current density, magnetic flux, etc.
9. "Strength" (acidity, etc. of processing mediums)
10. Radiant energy

The above list includes only those measurable conditions for which industrial instruments have been designed, developed, standardized and placed on the market. The purpose of this book being to acquaint the industrial engineer with the means which have been put at his disposal so that he may approximate "the one best condition" in the processes which are his livelihood, no descriptions will be given of purely scientific (non-commercial) devices applicable only to experimental work in the research laboratory. These, moreover, are limitless in their variety and new arrangements are constantly being designed, so that this subject is one for occasional promulgation in periodical literature—not for inclusion in a Handbook of everyday usefulness.

Composition and Properties. If the engineer strives to conquer variations in processing conditions it is because he desires that every product (resulting from any given process) be sold at a profit or used profitably in subsequent processes. To this end the product must meet definite specifications as to (1) purity and (2) physical and chemical properties. Specifications have for many years been checked in laboratories. A bewildering array of innumerable types of testing instruments has appeared. The *Bureau of Standards*, the *American Society for Testing Materials* and other societies are bringing order into this somewhat chaotic condition. Laboratory testing instruments are becoming standardized. Some of them have even become *industrialized* and now come within the scope of this book. By this we mean that they have passed from the laboratory to the plant. To illustrate:

*Since the first appearance of this list the author has been asked, in all seriousness, why he "did not include gravity." Gravitation, the universal "condition"—present in all manufacturing operations and processes, and in fact wherever matter exists—is excluded from this list for two reasons which to the author seem excellent; First, it cannot be measured except in the purely scientific sense of determining its one and only and invariable magnitude, *acceleration*—a universal constant like the speed of light—which for matter on the mean datum of the earth's surface has been found to be, in feet per second, 32 and a number of decimals that few remember offhand. Second, it cannot be controlled. However, *mass* is a property of matter, and instruments for measuring weight, and for controlling flows and proportioning by weight, are dealt with in this book.

1. A liquid product must have a definite specific gravity. This property is tested in the laboratory by means of a hydrometer—a glass cylinder whose degree of immersion at a definite temperature of the liquid gives the Baumé or other degree. Substitute a rugged steel float chamber, add a temperature compensation device, connect the float chamber into the outflow of the processing apparatus, and the result is a specific gravity recorder—an industrial process instrument. Specific gravity is not a processing condition.

2. A gaseous product must have a definite composition. In the laboratory we can analyze the gas. In modern plants there are automatic gas analysis devices which indicate and (or) record the composition. Such devices are industrial instruments, although composition is not a processing condition.

3. Another gaseous product—commercial illuminating gas—must have a definite heating value. In the laboratory this is determined by various calorimeters. Modern gas plants not only are equipped with automatic recording calorimeters but with devices which automatically maintain the desired calorific value.

4. A liquid product must have a definite acidity or alkalinity. As it flows out of the process tanks its hydrogen ion concentration is automatically recorded by an industrial instrument which moreover automatically maintains the desired property—by regulating the rate at which one of the components is admitted. This does not refer to acidity as a *condition*, i. e., the "strength" of the bath or medium in which a material is treated.

These examples show that the range of modern industrial instruments has broadened beyond conditions, such as temperature, etc., and today includes two additional fields of special importance to the engineer. These fields are:

1. The measurement and control of physical and chemical *properties*.

2. The measurement and control of *composition*. That is to say, automatic analysis and automatic control of mixing.

As in the case of the instruments relating to processing conditions, laboratory instruments relating to properties and composition will not be discussed, and only the successful industrial instruments will be described.

The Rôle of Industrial Instruments. It is only lately that engineers have come to realize the important rôle of instruments in their daily work. The process itself, of course, comes first in importance, whether it be combustion of coal in a boiler furnace, or smelting ore, etc. The equipment in which the process is carried on comes next—and consequently production men have for many years taken pains to study the best and most practical designs of furnaces, boilers, dryers, stills, autoclaves, ovens, evaporators, etc. Such pieces of equipment may be called primary or essential. These inanimate machines cannot function by themselves. They need regulation. Regulation is effected by means of auxiliary equipment. Because this auxiliary equipment is secondary, it has heretofore been somewhat slighted or taken for granted. Today the progressive industrial engineer realizes that there is only one best way of providing the one best condition. Hence his exacting demands upon the instrument manufacturers. This has led to a very useful co-operation between various industries on the one hand and instrument manufacturers on the other, which can be summarized as follows:

A new process is discovered. There are commercial possibilities. Production is begun on a small scale. Conditions (such as temperature, pressure, etc.,) are studied, that is to say, they are measured by means of

instruments. Measuring instruments are purchased. Next, in order to know not only what the condition, such as temperature *is*, but what it *was* over a period of time, recording instruments, are installed. Through study of all data collected, improvements are made in the process, in the primary equipment, and in the instruments. The engineer in charge now applies his intelligence and determines the exact degree for the one best condition—such as, say, temperature. He orders an automatic temperature controller. The instrument makers design and supply it. It is found imperfect in certain unexpected ways. Corrections are made and the automatic controller is now standardized. This, however, is not the final stage. The elimination of the human element from temperature control impels the manufacturer of the primary equipment to improve it further; and with both better primary equipment and secondary equipment at his disposal, the production engineer is encouraged to improve the process itself. It always is an endless cycle. A familiar illustration is the most important process in the rubber industry—curing or vulcanization. Rubber chemists years ago laid down temperature-pressure-time cycles for the vulcanization of various mixtures of rubber, filler, sulphur, and accelerator They demanded a type of instrument which had not yet been invented—a combination temperature-pressure-time cycle automatic controller. The instrument makers not only fulfilled this demand, but offered automatic devices making possible even more intricate curing schedules. The rubber chemists accepted the challenge and revised their schedules. Again the instruments makers provided the means of accomplishing these schedules Today every rubber chemist knows that "the sky is the limit" in the development of new and better curing cycles; he has but to formulate his requirements in terms of measurable conditions, such as temperature, pressure, and time, and the instrument maker will provide an adequate automatic device.

This illustrates the important role of industrial instruments—a role fully as important as that of the primary equipment, such as the furnace, autoclave, tower, or still.

Theoretically there exists or can be designed an indicator, a recorder, and a controller for each of the ten measurable processing conditions, and also for properties and composition. In practice, however, we find that only two conditions are of prime importance, namely, temperature and duration of process. We also find that one condition can often be regulated by regulating another, and that for practical purposes one instrument sometimes suffices, instead of three. Example: A multiple-effect evaporator. It would be an obvious extravagance to have liquid level recorders in addition to the indicators and controllers on each body, and it has been found sufficient to control the density of the juice issuing from the last effect. For a quintuple effect evaporator, including condenser, trap, and juice pump, a total of 18 instruments is found sufficient, although it is possible to imagine the application of 45 instruments to the evaporator, not counting the condenser, trap, and juice pump.

PRACTICAL DEFINITIONS

The foregoing may not be acceptable as a definition of industrial instruments. Nevertheless certain terms often used in connection with instruments now need to be defined. Fortunately their definitions have grown more and more exact in engineering practice, thanks especially to the *American Society of Mechanical Engineers*. Therefore the following will prove useful.

Accuracy. That industrial instruments are "less accurate" than "scientific" instruments is an unwarranted assumption and a loose generalization. In the first place the only accurate instruments are the counters, operation recorders, etc., dealing with units. There is no such thing as absolute accuracy in the instrumental measurement of non-numerical magnitudes such as temperature, pressure or rate . . and there never will be until man is able to count the molecules, atoms, electrons and quanta of matter, energy time involved in any measurement.* A bolometer may be so *sensitive* that its pointer will swing half way across its scale of 100 divisions in response to the glow of a candle ten miles away—and every engineer remembers the awe he felt when a professor first mentioned this; but if in five successive measurements of a constant radiation a bolometer read, 47, 52, 48, 54, and 49, its "accuracy" is obviously much lower than that of a kitchen thermometer which reads 211°, 213°, 212°, 211° and 213°F in five successive immersions in boiling water. Note that the averages are, respectively, exactly 50 and exactly 212°F. This rough illustration therefore suggests that the terms accuracy, inaccuracy, error, etc., need at least a brief discussion. Accuracy has to do with two radically different considerations which may be designated as (a) the intrinsic accuracy of the instrument, and (b) the accuracy resulting under the conditions of use. Accuracy is used to designate the extent to which the indications of an instrument approach true values of the magnitude being measured. The accuracy of an instrument can be determined by calibration, but it is important to note that this often determines the accuracy only for conditions of use similar to those maintained during calibration. One common method of expressing accuracy is to state that the instrument is accurate to within plus or minus a certain specific amount or a certain percentage at a certain point on the scale or between certain points on the scale. Thus a thermometer may be described as having an error not in excess of ± 0.5°F. between 100°F. and 300°F. For comparison of various instruments of similiar character among themselves the specific inaccuracy at normal indications is a most useful value. The specific inaccuracy is the ratio of error to true value. The numerical value may be the same or different for various points within the range of the instruments. As an example, assume a pressure gauge which reads 48 lb. when a pressure of 50 lb. is applied and 98 lb, when 100 lb. is applied. The specific inaccuracy at the lower point is 2/50 or 4%, and at the higher point 2/100 or 2%. This is characteristic of nearly all measuring instruments which carry a uniformly graduated scale.

Inaccuracy of an instrument is caused by features or factors in the instrument itself and has nothing to do with the effect of external conditions other than the value of the magnitude being measured. Its principal causes are:

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*For more extended discussions see:
Power Test Codes, Instruments and Apparatus, Part I; American Society of Mechanical Engineers, (from which quotations are made).
Measurements, Industrial and Scientific. Dr. W. Block, Director of Bureau of Weights & Measures of East Prussia; Translation by Instruments Publishing Company, Pittsburgh.
Variance of Measuring Instruments and Its Relation to Accuracy and Sensitivity. F. J. Schlink, Bureau of Standards Scientific Paper No. 328.
The determinateness of the Hysteresis of Indicating Instruments. F. J. Schlink, Journal of Washington Academy of Sciences, January 19, 1919.
The Concept of Resilience with Respect to Indicating Instruments. F. J. Schlink, Journal of the Franklin Institute, 1919.
Also Glazebrook's Dictionary of Applied Physics (5 volumes), Ferry's Handbook of Physics Measurements, Berliner's Lehrbuch der Physik in Elementarer Darstellung, Gehlhoft's Lehrbuch der Technischen Physik (2 vols.), Geiger & Scheel's Handbuch der Physik (24 vols.), Kohlrausch's Lehrbuck der Praktischen Physik, Wien & Harm's Handbuch der Experimental Physik.

(a) imperfect material, as variation in bore of a glass tube, etc.; (b) unavoidable physical phenomena such as capillary attraction, etc.; (c) imperfect construction which cannot be improved, such as the finite width of knife edges or points, etc.; (d) imperfect construction which can be improved, such as excessive friction, excessive lost motion, incorrectly cut cams, etc.; (e) unavoidable or partly unavoidable properties of materials such as the aging of glass and permanent magnets, etc. Inaccuracies arising from causes (a) are ordinarily of irregular character, causing more or less erratic errors throughout the range. Inaccuracies arising from causes (b), (c), and (d) are more or less regular in character and are responsible for the hysteresis loop of an instrument, the loop obtained by plotting instrument readings against true values, using the instrument first in an ascending sense and then in a descending sense. Inaccuracies arising from causes (e) are responsible for what is known as aging or drift in instruments. Within certain limits such aging or drift is not detrimental, although it does necessitate frequent calibration to guard against its effects. In certain cases it must be taken into account if erratic results are to be avoided. Thus a glass thermometer which is to be subjected to high temperatures must be artifically aged before calibration and use.

Sluggishness is a term used to indicate the amount of effect required to cause motion of the indicating part of an instrument. Thus a thermometer which at 400°F. requires a change of ± 5°F. to cause it to move up or down will have a sluggishness index of 5/400 or 0.0125. This factor is most useful when expressed as a percentage, giving 1.25% in the example cited "Passiveness" and "lag" are often used as synonymous with sluggishness Sluggishness is often thought of as the opposite of sensitiveness or sensibility. Thus it is common to speak of a thermometer as "sensitive to 0.01°F." meaning that it will respond to changes of that order. This is technically an incorrect usuage.

Sensitivity is defined as the rate of displacement of the indicating element of the instrument per unit change of the measured magnitude. That is, one of a group of comparable instruments which gives the greatest displacement for a given change in the measured quantity is the most sensitive. Sensitivity of instruments is a most important property, as with other things equal it is the thing which determines the degree of refinement possible in their use. Unfortunately instruments are not always designed and constructed in such a way that the total available sensitivity is useful. Thus an instrument may be so constructed that it is possible to read on its indicator the movement corresponding to a variation of one unit in the value of the magnitude being measured, but it may be so built that it will indicate values varying by as much as five units in successive trials with no change in the actual value being measured. The sensitivity of such an instrument is partly useless and is really misleading. A correctly designed instrument should have such sensitivity that the minimum readable movement of its indicator is not less than the amount by which the instrument may be expected to vary in successive indications of the same value of the measured magnitude. To be exact these requirements should be stated in terms of the mean for both indication and variation as both may vary from point to point throughout the range of the instrument. Sensitivity in excess of requirements, as set by the accuracy desired in a given set of measurements, is generally a detriment because it involves delicacy, slowness of operation, or some other undesirable quality.

Variance is a term used to represent the amount by which the readings of an instrument vary in successive indications of the same value of the measured quantity. Variance is due principally to (a) lost motion, which also affects the sluggishness or passiveness; (b) friction, which also affects the sluggishness or passiveness; (c) changes due to the stress-strain relation of springs in the force-resisting or restoring element of the instrument; (d) changes in the distribution of parts, as variation of position of pins in bearings or variation in the amount of liquid retained on wetted surfaces; (e) the immediately preceding history with respect to extent and speed of displacement; and (f) a great number of other more or less obscure phenomena. Variance due to friction can be partly eliminated by tapping the instrument just before taking a reading. Variance due to other causes can be kept at a minimum value by proper maintenance and proper handling.

Calibration. The exact procedure to be followed in determining the condition and accuracy of instruments varies not only with the instrument but also with the use to which it is to be put, the accuracy desired and other considerations. In general the calibration should include determination of the following throughout the range which is to be used: (a) sluggishness and its relation to the sensitivity of the instrument, and (b) accuracy, or error of indication at different points within the useful range.

For calibration procedures, plotting of hysterisis loops and correction curves, see the references listed in the footnote under *Accuracy* above.

Class, Type, Group, Model, etc. These terms are used indifferently in scientific, engineering and sales literature. There is urgent need for standardization of usage. It will not be attempted in this first edition. It is hoped that categorical meanings, as regards "industrial instruments," will be assigned to these words and to many others such as *series, regular* and *special*, etc. It is respectfully submitted that *number* be applied to the ultimate division, *series* to be the last but one, and *model* to be last but two, reserving *type* and *class* for divisions of broader inclusiveness, shared by many manufacturers. Some manufacturers are making intelligent use of the words *size* and *form*, but others use *type* and *class* for conveying morphological distinctions of like degree.

But what does it avail to establish a logical terminology pertaining to distributive order, when the basic nomenclature of the art is subjected to atrocious mutilations? It is a fact that in a localized industry, comprising between two and four dozen establishments in an Eastern state, recording thermometers are called *clocks* by many of their actual users. Just as the childhood of a nation must be taught the three R's as a foundation for engaging in arts and trades, so should men of all ranks in the instrument-using industries know at least the names and main objects of devices which, on the whole, make their work easier and their wages steadier. It is proper, therefore, to conclude this chapter with information on some of the *kinds* of industrial instruments—not the classes or types discussed in the different chapters but the *kinds*, denoted by participal adjectives in front of the names of instruments. The following is an attempt at such a glossary. It is without precedent and consequently it is not offered as official, or as complete, or as a new basis of classification. Nevertheless it is urgently needed; and if it is copied (with suitable local corrections) and circulated in instrument-using plants and departments, a good deal of confusion will vanish. Furthermore, it is requested that amplifications, simplifications, additions and other suggestions be sent to the magazine INSTRUMENTS, Pitts-

burgh, Penna., U. S. A., in order that subsequent editions of this Handbook will include revisions for the better. The arrangement is alphabetical:

Checking. 1. A specialized form of testing instrument, i. e., for occasional or intermittent, not continuous, use. 2. An instrument in continual use for managerial "checking" as of employees' in and out time, etc.

Controlling. An instrument which automatically controls, corrects, governs or regulates (1) the processing, working or storage condition or (2) the physical or chemical property of matter or (3) the proportioning to which it is applied. Generally used continuously and permanently installed.

Counting. An instrument or device that counts the number of units such as revolutions, strokes, etc. Examples: a hand counter for shaft revolutions, or an "electric eye" for counting either vehicles passing a point or articles traveling along a conveyor.

Curve-Drawing. A form of recording instrument, producing a continuous record of a variable magnitude. This designation is principally used in electrical engineering practice where it refers to recording instruments, and in pyrometric practice where it refers to recording pyrometers which furnish continuous records of the temperature of each thermocouple or resistance bulb.

Cycling. The designation cycling instrument is seldom used in industrial practice. A cycling controller (also known as a cycle controller, program controller, time-operation controller, etc.) is a mechanism embodying (1) one or more clockworks and (2) means for automatically performing predetermined operations at predetermined times in proper sequence according to either (1) a definite schedule in which all times are fixed or (2) a flexible schedule in which certain times depend on states, stages or conditions. The timed operations may be sudden, as opening or closing valves, or gradual, as in the case of a drying schedule or curing cycle.

Detecting. A signalling instrument or device giving merely a yes or no indication, usually visible (when audible it becomes an "alarm" instrument).

Indicating. 1. An instrument that shows that the scalar or numerical value of the "measurable magnitude" to which it is applied is at the time that it *is* read (or what it *was* shortly before, allowing for lag). Examples, a Bourdon gauge, a liquid-in-glass thermometer, a boiler gauge glass. 2. A detecting instrument giving a yes or no indication without assigning a scalar value, but provided with a visible indicating element. Portable as well as fixed forms are *industrial* so long as the purpose and construction relate to the plant rather than the laboratory.

Integrating. An instrument that automatically performs the mathematical operation of multiplying quantity-rate by time to give total quantity; or which directly indicates the total quantity, as of a fluid in units of volume, or electrical power consumed in kilowatt-hours, etc. Reserved for instruments applied to variables, not generally applied to counters. (See Counting).

Measuring. Any instrument capable of assigning a scalar or numerical value to any "measurable magnitude" (condition, property, effect, etc.) Examples: a foot-rule or a wave-length spectrometer, a grocer's scale or a geodetic torsion balance. Not, as a rule, applied to counting instruments and devices.*

*Whenever a new measuring instrument is devised and placed on the market an attempt is made (and very properly) to give it a name ending in -meter but not hyphenated. It occasionally happens that two or more new instruments appear almost at the same time in response to a new need, and that the various sponsors do not agree on a name. Thus we have viscosimeter and viscometer, plasticimeter and pastimeter, etc. But this is preferable to two words of which the second is meter.

Metering. In general a commercial type integrating instrument known as a meter. Special types are maximum-demand meters, etc.

Recording. Any instrument industrial or scientific which furnishes a time graph (generally on a moving chart) of the value of the "measurable magnitude" to which it is applied. It embodies an indicating instrument the indicating element of which (pointer, pen-arm, light-beam focused on sensitized paper, etc., etc.) traces the "record" which may or may not be a "curve." The record is permanent and therefore shows what the value of the measured magnitude was at a previous time. The record may be continuous or intermittent. One recording instrument may be applied to several measurable magnitudes.

Registering. Not a recording instrument, but a form of indicating instrument provided with means of registering maximum or (sometimes *and*) minimum values, such registering element "staying put" until manually displaced. Examples: a maximum-registering thermometer, a cylindrical tire pressure gauge.

Sampling. The A. S. T. M. has apparently sanctioned the designation "sampling instruments" for devices which, in spite of their being beautifully made in strict conformity with the Society's specifications, are implements and not instruments. (This involves, of course, a discussion of the definitions of instrument, apparatus, device, machine, etc. The author will not go into it here beyond making the foregoing statement).

Signalling. An indicating, recording or controlling instrument provided with means for visible or audible signalling at predetermined and usually adjustable "points" or scalar values.

Testing. Implicitly a non-industrial instrument, not permanently installed on a piece of equipment but kept in the laboratory (or taken out on the job) and used as the occasion arises.

Timing. 1. A time measuring instrument or timepiece. 2. A form of recording instrument, as an operation recorder. 3. An alarm or signalling timepiece which may be set. 4. A controlling instrument which causes an operation to be performed automatically at the end of the period of time for which it is set, such times being ordinarily related to the manual setting operation, but in certain forms to a state, stage or condition independent of the manual setting. Elaborate forms of industrial timing-controlling instruments are preferably called cycling controllers.

Totalizing. 1. Any counting instrument or device. 2. Any integrating instrument.

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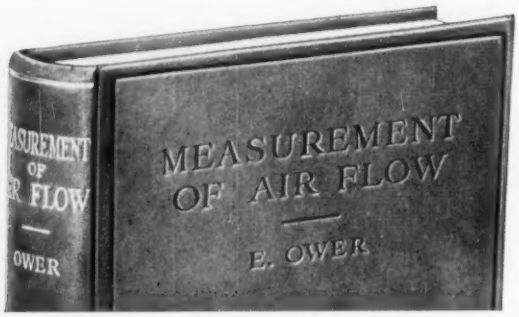

The Measurement of Air Flow

By

E. OWER, B.Sc. (LOND.), HONS. I., A.C.G.I.

Bramwell Medallist; Member of the Institute of Heating and Ventilating Engineers; Assistant in the Aerodynamics Department, National Physical Laboratory.

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CHAPTER I *(Concluded)*

The Historical Development of the Measuring Science and the Systems of Length and Weight

by

DR. FRITZ PLATO
Direktor a. d. Reichsanstalt fuer Mass und Gewicht

5. THE MATERIAL OF MEASURES

(a) Measuring rods. For the manufacture of measuring rods, metals and wood are generally used. In addition ivory, bone, hard-rubber, all kinds of celluloid, also pressed paper and several other materials are used. For measures of lesser accuracy, wood deserves preference above all other materials, not only due to its cheapness, which after all also has a considerable influence, but mainly due to its great insensitiveness to temperature changes, which makes it particularly suitable not only for the measures used in commerce and trade, as measures for long goods, collapsible rules, etc., but also i. e. for drawing rules or pendulum rods, for the surveyors rod and the foresters gage exposed to extreme variations of temperature. To this advantage is opposed the disadvantage that wood is subject to changes due to the influence of the humidity of the air, on which no definite information exists. It is only certain that wood rods elongate with increasing humidity. According to Hildebrand[8], Goulier[9], and Stadthagen[10], the value of elongation varies with the relative humidity of the air. Stadthagen, on the strength of his tests, arrives at the conclusion, that under average conditions, the change of length of a meter amounts to 0.01 mm for each 1% change of relative air humidity. The results which were obtained in different ways do not agree very well, a continuation of the experiments, however, would hardly be of value as apparently quite indefinable and unobservable influences, i. e. constitution of the soil, growing conditions, time of cutting of tree, etc., have a certain influence on the amount and kind of relation of length change in the wood and humidity. Efforts have been made to counteract the action of humidity by impregnating the wood with materials which neither absorb water, nor permit it to penetrate as linseed oil, paraffin oil, shellac, etc., but with limited success. For better measures, therefore, wood cannot be used. On the other hand, it will be difficult to replace it by other materials for measuring rods. In addition, its light weight makes it superior to metal. Lüdemann[11] has written a very compre-

[8]Hildebrand, Untersuchungen ueber den Einfluss der Feuchtigkeit auf den Laengenzustand von Hoelzern and Elfenbein. Annalen der Physik und Chemie, Neue Folge, vol. 34, 1888.
[9]Lallemand, Etude sur les variations de longeur des mires de nivellement, d'après les expériences du colonel Goulier.
[10]Stadthagen, Untersuchungen ueber die Abhaengigkeit der Laengenaenderung von Holzstaeben von Feuchtigkeit und Temperatur. Annalen der Physik und Chemie, Neue Folge, vol. 61, 1897.
[11]K. Luedemann, Laengenaenderungen Holzerner Mess-und Nivellierlatten.

hensive paper giving numerous bibliographical notes to which attention may be especially directed here.

Other materials, besides wood and metal, are too rare to mention. Of metals, steel is the most widely used since it combines great strength with sufficient hardness both of which are qualities which make a material especially applicable to the manufacture of measures because strength guarantees a certain protection against sagging; hardness, is a prerequisite for a clear and uniform engraving of the divisions. A third requirement must be met by materials for measures, namely, that they are sufficiently resistant to impurities of the air. This is, of course, not the case for steel since it is attacked both by water and by acids, it rusts. Delicate steel-measures, therefore, must be permanently covered by a layer of grease, i. e. vaseline free from acid, and they must not be handled with the bare hands. In end measures, the measuring body is preferably covered with a suitable protective lacquer and only the end-faces are left uncovered. These are highly polished. In line-measures, at least the surface with the divisions is treated in the same manner. Smaller measures are electro-plated with nickel and then highly polished. The nickel-deposit is especially hard and permits the drawing of very fine divisions and also offers a most excellent protection against rust.

Besides the danger of rusting, hardened steel-bodies are further subject, after hardening, to changes in length, usually to contractions, but also to expansions, even for years. The reason for this is obviously to be found in stresses which occur in hardening. The Normal-Eichings-Kommission was perhaps the first to call attention to these conditions[12]. Very thorough investigations have been made by the Physikalische Technische Reishsanstalt[13] from which it appears that the change in steel-measures due to hardening stresses can be removed with certainty by tempering in an oil-bath at about 150°C. for about 10 hours. In the shop, one is generally satisfied to harden only the faces subject to wear in end measures and gages, i. e. in end measures the ends only, and to leave the body otherwise unhardened. An assurance that the measures do not undergo changes is, however, not assured by this treatment. Manufacturers of measuring tools have done considerable work on this point but, for obvious reasons have published nothing on it.

Great hopes had been placed on the application of nickel-steel. This alloy has been particularly investigated by Guillaume, once director of the International Bureau of Weights and Measures. He published a comprehensive report[14] in 1898 which was reprinted unabridged in the Deutsche Mechaniker-Zeitung of 1898. The later communications of Guillaume add nothing new. They show that an alloy of 36 parts nickel with 64 parts steel possesses such a small expansion—roughly 1 μ per meter and degree C. that it can be considered as being almost without expansion. This property makes it very valuable for surveying. As a matter of fact, measuring wires and tapes 40 to 50 m in length have proved excellent and are used especially in the tropics preferably in place of measuring rods. This alloy, called Invar, is also very suitable for watch-springs and clock pendulums. Invar is equal to hardened steel as regards strength and hardness, yet it cannot

[12]Thermische Nachwirkung bei Metallen. Mitteilungen der Kaiserlichen Normal-Eichunga-kommission, Series 1,page 13, 1886, Elastische und thermische Nachwirkungen bei Metallen. Same report, page 116, 1889.
[13]Leman and Werner, Laengenaenderungen an gehaerteten Stahl. Werkstatttstechnik, 1911.
[14]Guillaume, Bulletin de la Société d'encouragement pour l'industrie national, 1897.

be used for finer measures as one has so far not been entirely successful in removing its internal stresses or at least to a uniform degree even by continued tempering for a long time. Except for steel brass is most generally used for making measures. It does not possess the same strength as steel but is free of stresses and formation of rust. For end measures, brass, as also bronze, as a rule is too soft. Finer line-measures are preferably provided with an inlaid strip or inserted cones of silver which is attacked, by air and its impurities, in a still lesser degree than brass. The silver is highly polished and carries the divisions which are especially distinct on the light background. If the strip is well hammered into a dove-tailed grove such measures are very good, since silver, even if heated up to 100°C. suffers no displacement in comparison with the body of the measure; on the other hand the combinations of metals with very different elongations as i. e., bronze with platinum, steel with silver, etc., are not recommended.

Pure silver and platinum, due to their softness, cannot be used for end measures, and for line-measures only where it is a question of short scales or such which are inlaid into a solid base, i. e., a measuring body, or the table of a measuring machine. On the other hand, the alloy of 90% platinum and 10% iridium selected for the prototypes of the metric system seems to be a very suitable material for measures of all kinds due to its steel like strength. The high price of course, make it prohibitive for general use.

(b) Weights. Of special importance for weights, in addition to hardness and strength is the resistance to the materials with which they come in contact in use, i. e., for the smaller weights the resistance to the influence of the air and its impurities, for the commercial weights resistance to the materials which they have to weigh. For the commercial weights admitted in public-traffic the calibration rules demand further that we ghts of equal mass also have equal height so that a purchaser can see without difficulty that he received proper weight. Iron and brass are, therefore, only used for these. Both metals have their advantages and their disadvantages. Iron is recommended due to its cheapness. It is mainly used in the form of cast iron but this cannot be machined, and also spalls easily due to its brittleness when dropped on a stone floor. And last, it is extremely sensitive to humidity, salts, and acids. Since cast-iron weights cannot be corrected by machining or filing, when casting, a pocket is left in the interior of the body (the calibration cavity a in Fig. 14) which connects with the outer air by a small channel (the calibration opening b). The weight is made too light by a prescribed amount. Then the pocket is filled with fine lead shot until the mass corresponding to the standard value is obtained, and the calibration opening is closed airtight by driving a lead stopper into it. Efforts have been made to reduce the formation of rust by coatings of lacquer, oil paints, etc., plating with metals like zinc, tin, brass, etc., dipping in oil, shellac, etc., by enameling, oxidation, coloring, etc. A certain surface protection is obtained therewith but one has so far not been successful in making this so perfect that small holes, hardly perceptable to the naked

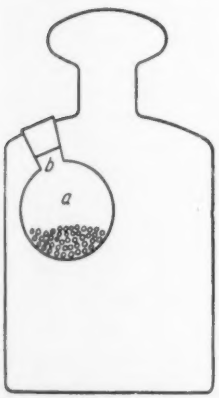

Fig. 14. Weight with adjusting cavity *a* and calibrating plug *b*.

eye, are not present, which are the starting points for rusting. Besides, there remain smaller or larger cavities in casting in the interior of the weights which, even with the best protected surfaces still connect with the outer air through fine pores and cause rusting from the interior outwards which becomes obvious in a continuous increase in weight (increase of mass) due to absorption of oxygen. The amount of increase depends on the density of the casting and on the time. It is greatest immediately after finishing. For instance, 2 pieces of 20 kg which were coated with hot asphaltum lacquer, showed the following increases: after 7 months 1380 mg. after further 7 months 890 mg. after 6 months 600 mg. after 5 months 480 mg. after further 22 months 1690 mg. that is more than 5 gms. in 47 months. After 4 years the average increase dropped to about half so that further increases could be expected. A better behavior was shown by standard weights of finest sand-casting (by Borsig, Berlin) of which i. e., a 50 kg weight increased only 972 mg in the interval from 1879 to 1914, the best results were shown by chilled castings (Gruson, Magdeburg), but these pieces even at present 20 years after their manufacture, also show a further quite distinct increase in weight. For commercial weights this fact is without importance since their wear greatly exceeds the increase.

Copper and its alloys of which mainly brass, bronze, and nickel-silver, are used for weights, are not porous all through, as iron, but show only isolated bubbles in the interior, and they oxidize only to a limited degree. In general traffic, weights made of these materials have the disadvantage in comparison with iron weights that they wear faster due to their greater softness, especially by rubbing on the marble store counters and by scrubbing when cleaning. Finer weights, as are required in physical or chemical laboratories, are gold or nickel plated to make them more resistant to acids and salts and to close the pores connecting the holes in the interior with the outer air. This treatment, however, may even increase the danger of inner oxidation as electrolyte having filled the cavities now combines in its turn with the constituents of the air. It is an excellent precaution to boil such weights several times with pure water. Otherwise, electrically deposited coatings, especially such with high polish, have proved their worth for weights of greater accuracy. A nickel-plated kilogram-piece i. e. (of Stueckrath, Berlin-Friedenau) in 12 years showed a reduction in weight of only 0.05 mg; the somewhat softer gold-plating wears a little more, but showed changes of less than 0.1 mg. Although it will be discussed more fully later it may be expressly mentioned here that weights with screwed-in heads should not be used, at least for finer weighing, since their mass is greatly dependent on the variations of air pressure as a result of the large cavity connecting with the outer air.

Platinum and platinum-iridium are used only for the highest grade weights. According to experiences made so far, this alloy is particularly suitable for this purpose. Of course, these weights must be treated with the utmost care as the material is comparatively soft and is rubbed off on hard supports. Air with its impurities does not exert any influence on platinum and its alloys. Of early investigations on the variation of platinum weights, those of Loewenherz[15] and Stadthagen[16] must be mentioned.

[15]Loewenherz. Untersuchungen ueber die Veraenderlichkeit von Platin-Gewichtsstuecken. Metrononische Beitraege der Kaiserlichen Normal-Eichungskommission, No. 2.

[16]Stadthagen. Ueber die Veraenderlichkeit von Gewichtsstuecken. Wissenschaftliche Abhandlungen der Kaiserlichen Normal Eichungskommission, Vol. 4, 1903.

Very comprehensive observations and tabulations have been made by Kramer which have not been published. According to this, the old Prussian prototype, a kilogram piece made of platinum, in 1860 during the years from 1890 to 1914, lost only 0.04 mg of mass by wear in regular use.

In addition to the larger brass weights, also in simpler sets of weights the fractional grams of from 500 to 50 mg. are often made of small sheets of platinum. They have proved their worth in every respect. For the smallest weights from 20 mg downward, small discs or wires (riders) of aluminum are used.

Weights of rock-crystal are often employed in physical and chemical laboratories as they do not wear or oxidize. They must however, be handled with great care because they easily become electrified and can then falsify the readings by the effects of attraction on the metal parts of the scales. It is also difficult to properly correct them. And finally, the absorption film which forms in air on every surface, seems to be the cause of certain variations in rock-crystal which cannot be overlooked.

6. SAFE-KEEPING AND TREATMENT OF MEASURES

Special instructions are not necessary for the commercial measures and weights. Here the government takes care of their permanent accuracy within definite limits prescribed by law, first by new calibrations and recalibrations, then by inspections in the stores from time to time. For finer measures it is sufficient to keep them in a wooden box lined with velvet, silk, leather, etc. But care must be taken that the glues with which these materials are fastened to the wood do not contain acids, and that the rods have sufficient play in the boxes so that they can expand freely and not get stuck even at the highest temperatures where they are kept.

More attention must be given to the care of weights. As a rule, they are kept, as the measures, in boxes lined with some material which is entirely sufficient for weights of an accuracy not exceeding 0.1 mg. Here also the condition of an acid-free glue is important. Rock-crystal weights, even such of lesser accuracy, should never be kept in lined boxes because they become electrified when taken out, by friction with the cloth. The most suitable way is to place them on three sections of an ivory ring which are glued to a frosted glass plate, and to cover them with a glass bell with a ground glass joint as protection against dust. All finer weights should be kept in a similar manner. While a loss of mass, even for metal weights, need hardly be feared by friction with the lining of the boxes although it might take place, the influence of dust should not be underestimated. Dust does not weigh anything, is a much-heard maxim which, however, is only partly true. Recent observations have shown that the dust combines with the liquid film on the surface of the weights to form a layer of dirt the mass of which cannot be neglected in finer weights. A simple dusting will not remove this layer, also a careful rubbing with leather is not very successful especially as leather is seldom free of fat and, therefore, puts a very undesirable fat film on the weight. For this reason, storage on leather should be avoided. Quite useful is wiping the surface with acid-free tissue paper, but washing with pure benzine has proved to be best, which is not harmful to the weights, and is also known as the best method at the International Bureau of Measures and Weights. How much this layer of dirt may amount to, can be seen from the fact that a kilogram piece of copper which for years always increased in mass, became 0.4 mg lighter by washing with benzine. Of course, after cleaning one must wait before reweighing the piece until

the liquid film destroyed by cleaning has again formed on the surface. If weights are protected in the above mentioned manner against dust and dirt such collection is not to be feared on the surface. It may be said only for the sake of completeness that finer weights should not be handled by the fingers, but with forceps, large weights with a fork or tongs, very large ones with a leather-lined claw.

7. STANDARD TEMPERATURE AND USING TEMPERATURE

Every body changes its volume under the influence of heat, generally in such a manner that, with increasing heat, it expands, i. e., increases its volume, with decreasing heat contracts, i. e., decreases its volume. The best known exception of this rule is water which has its greatest density and therefore its least volume, at +4°C. and from this point, expands both for increasing and decreasing temperature until it goes over into steam on the one hand, on the other becomes ice and solidifies. The law for volume holds good, of course, also for the individual dimensions, length, width (thickness), height, (depth). It is therefore impossible to speak quite generally of the volume, outer or inner, or of the length, width, and height of a body, but it is necessary, in order to have a clear idea, to each time add at which temperature the volume or the given dimension is to hold good. Since errors may easily occur in this way, and also the comparability of bodies among themselves is lost if each singly has the prescribed dimensions at another temperature, especially as the various materials also have quite different expansions, it has been agreed upon for the measures and weights, either in the country of origin of a measuring system, or internationally, that they must correspond to their nominal value at a predetermined temperature. This temperature is called the standard temperature or starting temperature of a measuring system. In itself it is of no importance from which temperature one starts. As a matter of fact, the different measuring systems use the most varied temperatures. In the metric system, the unit of length is defined as the distance between the end lines of the international meter-prototype at the temperature of melting ice. The standard temperature of the metric system is, therefore, 0°C. In the old Prussian system, the standard temperature was fixed at 13°R (16.25°C.), while the standard temperature of the English system is 62°F. (16.67°C.). In the previous definition of the meter as the ten millionth part of the earth-quadrant the temperature is of no importance whatever, it has become so only when the unit was materially represented and embodied. At any rate, to correct a most wide spread error, the unit-length itself is, in every system, independent of the temperature, it can, therefore, not be spoken of as a meter at 18°C. or a yard at 100°F.; always and under all circumstances a meter, or a yard is that distance existing at 0°C. or 62°F., respectively between the determining marks on the prototype. One must always keep in mind that a measuring rod of steel, of brass, etc., which is to represent one meter (steel-meter, brass-meter) must have the prescribed length of a meter at the standard temperature of the system, i. e. 0°C. If it is assumed, as it is usual, that the expansion of brass for 1°C. and 1 m amounts to 0.0185 mm, and that of steel to 0.011 mm then an accurate brass-meter should have at 20°C. a length of 1.000370 m, a correct steel-meter of 1.000220 m. Both meter rods must therefore differ by 0.15 mm at 20°C.

Not to be confused with the standard or starting temperature is the temperature of use, or shop temperature. In instruments, machines, etc., often for technical reasons many different materials must be used with one

another, i. e., shafts of red brass and bearings of steel, in scales beams of brass and knife-edges of steel, etc. These parts must fit together at the temperature conditions met with in operation, i. e., in shops, engine rooms, etc., which means at temperatures of about 10° to 20°C. This temperature is consequently designated as temperature of use. Since shop rules and gages and the corresponding check-gages are generally manufactured of steel the prevailing temperature must be taken into account in dimensioning of pieces of other metals due to the difference in the expansion which requires calculations not usually left to the average workman. Technical interests have therefore proposed the stipulation generally of a standard temperature of 18°C. With equal right however, a temperature of 25° or 30°C. for the tropics, in northern countries of 5° or 10° could be stipulated. It is also entirely overlooked that the standard temperature is entirely independent of the temperature of use. It seems doubtful whether the starting temperature of 0°C. is really very appropriate for practical requirements because the more the two temperatures agree the smaller is the difference of elongation between the different materials. With a starting temperature of 15°C. and a temperature of use of 20°C. the difference in length would amount to not quite 0.04 mm for measuring rods of brass and steel. The starting temperature of 0°C has, however, the great advantage of being independent of the different temperature scales and of being easily and absolutely correctly reproducible as the temperature of melting ice. To give up this advantage by selecting another starting temperature cannot be recommended. On the other hand, it can be left to the mechanics to adjust their rules, gages, etc., in such manner that they have the desired value at the temperature of use. For instance, a measuring rod of steel which is to have the exact length of one meter at 20°C. must be shorter by 0.22 mm, one of brass by 0.37 mm at 0°C. Also it should not fail to state conspicuously at what temperature the nominal value holds good as otherwise mistakes might easily occur as it will be assumed that a designation of length in the metric system can only refer to the starting temperature of the metric system. Numerical values of the expansion of different materials can be found in any chemical-physical and engineering tables but it must be specifically mentioned that in every case where the accuracy of rules, gages, etc., must be greater than 0.1 mm, as i. e. for check gages and measures for the correction of the former, etc., the expansion must be determined individually, as the expansion of the various grades of steel, the various copper alloys, etc., can vary considerably from each other according to their manufacture and composition.

The mass of a body is not influenced by the temperature, for measures of mass the standard temperature has therefore no importance. For measures of volume the matter stands exactly as for measures of length. The unit measure of volume, the liter or cubic decimeter, (on the difference between the two see page 401, Instruments, Nov. 1929) does not contain in its definition the temperature; the volume occupied by the mass of 1 kg of pure water, etc., is independent of temperature. But if this volume is represented by a container, a volume measure, then it must be stated at what temperature it represents or contains one liter. Since the temperature of melting ice, as already mentioned, has been agreed upon as standard temperature of the metric system, a liter measure, as every volume measure, must correspond to its nominal value even if it has a temperature of 0°C. If it is used at another temperature the difference of its contents due to the temperature must be taken into account. In commerce this can be neglected

as it amounts to only about 0.7 ccm for an enameled iron-measure of the size of a liter for 20°C, and for an aluminum measure to 1.1 ccm; for measures of scientific and technical investigations this must, however, not be lost sight of. In order to avoid the calculation necessitated hereby, chemists very often make their measuring devices, mostly of glass, so that they correspond, at the temperature of use, to their metric nominal value. As temperatures of use occur 15°, 17.5°, 18°, 20°C., etc. In such cases the temperature must be stated just as on the measures of length on the containers—pycnometers, measuring glasses, burettes, pipettes—at which they possess their nominal value. Such containers are then not liters, and it would be better to drop this custom as it makes the comparison of investigations carried out by different observers and at different times extremely difficult particularly if very specific statements on the temperature are not made. So, for instance, the use of the so-called Mohr's liter, that is a container taking at 15°C. just one kg of water if weighed in normal air with brass weights, has made many other observations absolutely valueless.

Contact Cable (Nagy Patent)

(Bishop Wire & Cable Corp.)

The invention consists of a water proof, dust proof and acid proof cable about the size of an ordinary lead pencil, which, when compressed at any point in its entire length, throws a switch, turns on a light, sounds a signal or does a thousand things which formerly required direct contact with a button or switch at a given, stationary point. In other words the cable is one continuous switch along its entire length, whether it be fifteen or fifteen hundred feet.

The myriad of uses to which the cable may be put are limitless: in the home for electrical devices, lights, radios; in banks and other commercial places of business as a protection against holdups; in mines and other underground operations where, in an emergency, signal buttons may be at remote places; in power plants as life savers and time savers, and finally in automatic traffic control.

The cable has a novel type of construction. Two conductors, enclosed by the outside insulation, are left bare but separated from each other by an "isolating cushion" of rubber. When pressure is applied this "isolating cushion" yields and permits the outer conductor to contact with a wire, which, in turn, is always in contact with the inner conductor, thus closing the circuit. When pressure is relieved the "isolating cushion" returns the outer conductor to its normal position.

Used with a relay switch the Bishop Control Contact Cable becomes operative at the point of pressure—wherever the operator happens to be standing.

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Heat Flow Meter-Model 553

*W. N. Goodwin, Jr.**

THE enormous and constantly widening use of heat insulation materials presents an ever increasing need for measuring their effectiveness. Up to the present time such measurements have been very difficult and time-consuming and withal subject to considerable error. The Weston Heat Flow Meter is an instrument designed to overcome these difficulties and when properly used will be of great benefit to Architects, Designing and Heating Engineers, Power Plant Engineers, Refrigeration Engineers and a host of others responsible for satisfactory and economical heat insulation. This device renders the measurement of heat flow almost as simple and direct as the measurement of electric current by means of an ammeter.

Designing and Maintenance Engineers in looking over their steam plants have often wondered how much heat they were losing from piping or from furnace or flue walls, or were confronted with the problems of deciding on the most efficient kind of pipe covering or the kind of material best suited for furnace walls and have often wished for some simple instrument to indicate directly the answer to their problems.

Architects and Heat Engineers also have been in a similar quandary when considering heat losses through walls of buildings or when deciding as to the best kind of wall material in regard to their heat insulating properties.

Refrigeration Engineers must know the rate of transmission of heat through the walls of refrigerating apparatus in order to determine the efficiency of various wall materials.

As stated previously, the measurement of the rate of heat flow and the resulting efficiency of the insulation have heretofore been very difficult and time-consuming operations, as for example:

The rate of heat flow from steam pipe requires the use of considerable length of pipe arranged so as to be drained of condensed water at the beginning and end of the section.

The weight of water condensed in the measured length during a given time together with the temperature of the steam and water were used to compute the rate of heat flow from this section.

In refrigerating apparatus it has been necessary to employ a calorimeter method which in reality is a laboratory problem and not adapted to commercial work.

The measurement of heat flow has not heretofore kept pace with other measurements, such as for example those of electrical quantities.

The Heat Flow Meter has been designed to overcome this handicap in heat measurements. The theory of operation is based upon patents by Dr. Ernest Schmidt, of Germany. It indicates directly on a scale, without computation, the rate of heat flow through a surface in B. T. U. per square foot per hour, or other convenient units. This instrument consists of a sensitive indicating millivoltmeter (Fig. 1) used in connection with a standard heat conductor made in the form of a thin rubber belt. The belt is placed in the heat circuit, as for example around the surface of a covered steam pipe, so that the heat to be measured must pass through it.

*Chief Engineer, Weston Electrical Instrument Corporation

Fig 1

Embedded in the belt just below the surface are a large number of thermo-couple junctions, one set of which are on one face and the other on the opposite face. These couples are connected in series and by means of binding posts on the belt may be connected to the indicating instrument.

Figs. 2 and 3 illustrate the method of using the belt to measure the rate of loss of heat from a steam pipe. The central belt "m" is the measuring conductor, and the belts "g" on each side of the measuring belt are for the purpose of equalizing the flow of heat in the immediate surroundings. The outside belts are not supplied with thermo-couples.

The proper binding posts of the indicating instrument are connected to the binding posts on the belt "m" as shown.

Where the circumference of the pipe is greater than the length of the belt, the three belts may be laced independently side by side by means of cords, using the hooks provided at the belt ends for that purpose. Where the circumference of the pipe is less than the length of the belt, the three belts may be laced together with the measuring belt in the center. The three belts are then wound around the pipe helically. It is necessary to have the

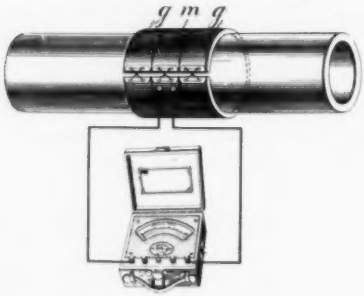

Fig. 2

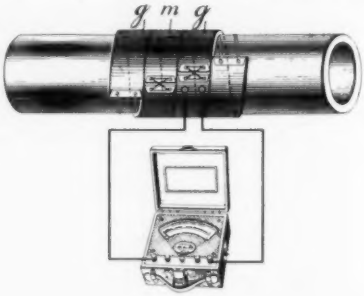

Fig. 3

entire lower surface of the belts in intimate contact with the surface from which the heat flow is measured. The instrument then indicates directly on the scale corresponding to the range selected, the rate of heat flow in B. T. U. per square foot per hour.

The temperature compensating switch provided on the instrument should be set to correspond with the temperature of the room in which the instrument is to be used.

Theory of Operation. In Fig. 4, P is a section of one wall of a steam pipe, for example, C is the lagging consisting of insulating material, and it is desired to measure the outward rate of heat flow represented by arrows H.

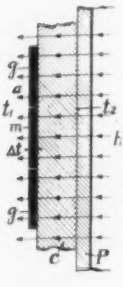

Fig 4

The rate of heat flow depends upon the conductivities of the pipe, and covering, and air contacts and upon the temperatures t_2 and t_1 inside the pipe and of the outside air, respectively.

If H is the heat flow per unit of time over a unit of surface, and "k" is the combined heat conductance from pipe to outside air for the same area. Then $H=(t_2-t_1)k$, that is, the product of the difference in temperature by the conductance.

The measuring belt "m" is placed in contact with the outside surface as previously described.

When the heat flow has become stabilized, which may require 1 or 2 hours, or longer, the heat which originally passed directly into the air from the portion of the surface occupied by the belt, now passes through the belt, except for the slight change resulting from the added thermal resistance of the belt, which is approximately 200 thermal ohms per sq. cm. A conductor has a resistance of one thermal ohm when a difference in temperature of 1°C. will result in a heat flow at the rate of one watt or 3.415 B. T. U. per hour.

The flow of heat through the belt causes a difference in temperature $\triangle t$ between the two faces of the belt, which generates a thermo electromotive force in the thermo-couples arranged on the two faces, and has a value proportional to this temperature difference. If the conductance of the belt is K_o and its area is A then the rate of heat flow H per unit area, per unit time is $\frac{K_o \triangle t.}{A}$

Since the thermo electromotive force E is proportional to the temperature difference $\triangle t$, it follows that H is proportional to $\frac{K_o E}{A}$ or its equal to a constant times the instrument indication.

The belt and instrument may, therefore, be calibrated in terms of heat flow and the values read directly from the scale. The instrument is calibrated in B. T. U. per square foot per hour, and has two scales 240 and 120. There is an additional scale calibrated in millivolts from 0 to 18MV. intended to be used, if desired, in connection with a standard thermo-couple for measuring temperature.

THE specifying of instruments and devices for measurement, testing and control starts with engineers, works managers, research engineers, test engineers, routine laboratories, consulting engineers, etc.

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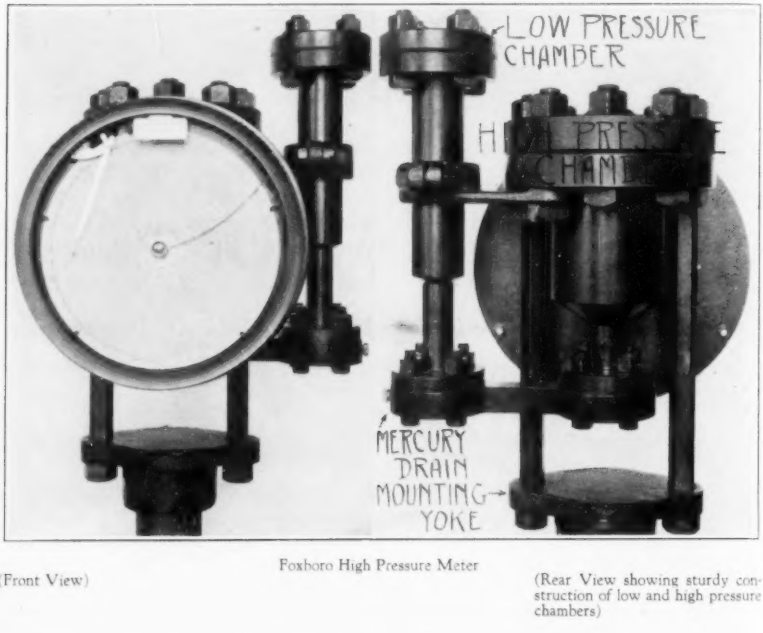
A High Pressure Meter

(Foxboro Company)

The increasing use of high pressures for boilers and for process work has led to the development of a new flow meter guaranteed to stand a working pressure of 0 to 5,000 pounds per square inch. It has been built for measuring the flow of gas, air, steam, hot oil and gasoline.

While retaining all the features that have made Foxboro Orifice Meters so well known, the pressure chambers of this new meter have been so constructed as to meet the higher pressures with absolute safety. A glance at the accompanying illustration will show the sturdy construction of this meter. All working parts subjected to pressure are drop forgings, and every part is specially designed for high pressure work.



(Front View)

Foxboro High Pressure Meter

(Rear View showing sturdy construction of low and high pressure chambers)

All known errors and variables have been eliminated, and the new meter has no unknown quantities and no inherent defects. It is calibrated to read and record in terms of flow and may be equipped with an integrator that reads direct without multipliers the total flow in gallons or feet or pounds.

The combination of four great factors—accurate coefficients, a differential measuring device that is inherently accurate, an integrator that can be depended upon, and pressure chambers that will meet any commercial condition—results in a high pressure meter of extreme simplicity and accuracy.

Combustion Balance in Multi-Cylinder Internal Combustion Engines

*Claude E. Cox**

MULTI-CYLINDER motors for motor cars, aeroplanes, motor boats and power plants may be balanced mechanically by the most exact methods and still not run smoothly if the combustion balance is not within the required limits.

Indicator cards showing the pressure conditions in each cylinder at all points of the cycle are the most direct indication of combustion conditions and because of the rapid changes in these conditions indicator cards must be taken from all cylinders at the same time. For ease of comparison the cards should all be in phase.

An enormous amount of work has been done in the past several years with an instrument which produced indicator cards of this type and the results obtained established beyond all question the value of this method.

The most useful cards are of the "pressure time" type in which the base line represents degrees of crank angle. A complete card covers four strokes of the piston and starts usually with the intake stroke. The cards are drawn on paper fed from a large roll so that consecutive cards can be drawn continuously.

The chart herewith shows only the "pressure peaks" which cover 275 degrees of crank angle including the compression and part of the expansion. Many cards are recorded on a short chart so that an easy analysis of combustion conditions can be made.

The cylinder numbers are at the left and the cards are lettered from left to right. It is evident that cylinders 1, 4, 7, and 8 did most of the work when card (a) was drawn; that cylinders 4, 8, maintained high pressures until the choke was released; that cylinders 3, 6, did no work, showing nearly normal compression cards; and that the pressures in cylinders 2, 7, failed rapidly as the motor warmed up.

As the test proceeded the frictional resistance of the motor and car became less and the throttle was closed slightly to maintain a fixed speed. The cards show the decreased amount of work required.

After the choke was released cylinders 1, 7, 8, showed very poor combustion, and 8 improved slightly as the manifold temperatures increased.

The maximum pressures shown are only 82 pounds per square inch showing well the sensitivity of the instrument.

The comparison of charts made with different manifold or carbureter equipment not only eliminates at once the "personal equation" so often present in comparative tests but puts on paper a permanent record, the careful study of which reveals combustion characteristics not to be found by any other method.

The cards shown are of the "Integrated Type" in that each card is made up of individual cycles. Such cards represent more accurately the working conditions than individual cards. The instrument used produces charts 17 inches wide with a 2 inch space available for each card. The chart shown (on the following page) is about one quarter size.

*Director, Commercial Engineering Laboratories.

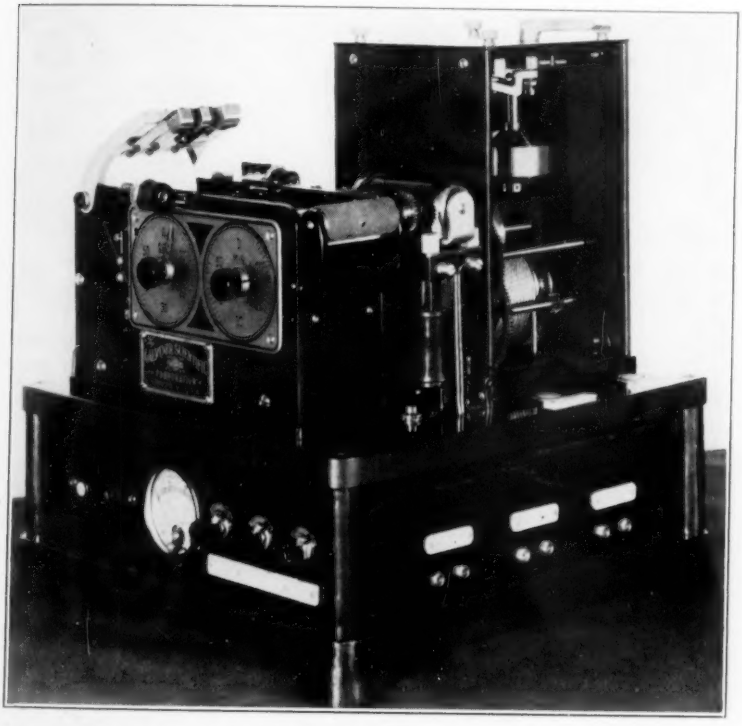
Illustration for Combustion Balance in Multi-Cylinder Internal Combustion Engines. See previous page.

Printing Chronograph A380 Design—1929

(Gaertner Scientific Corporation)

The instrument is, in general design, similar to the Printing Chronograph constructed by the late Professor Hough of the Dearborn Observatory of Northwestern University, but differs principally in respect to the control which is of our own design and assures an accuracy of 1/100th of a second.

The principal components of the Chronograph consist of a powerful driving clock, the printing and controlling mechanism, and the necessary operating Relays, together with accessories, such as switches, contact keys, etc. The clock with printing mechanism and controlling device is mounted on a heavy bakelite plate which forms the top of a case in which the relays, fuse blocks, and other accessories are mounted. Access to the case can be obtained through a removable panel.



Driving Clock. The clock is of improved design, dust-proof enclosed in a heavy brass case with plate glass sides, removable to allow access to the gearing. The governor is of friction-type with the pendulum arms made of "Invar." In general the construction of the governor is of the same type as used by us for over 30 years on astronomical driving clocks and chronographs and permits extremely close regulation. The gears are accurately cut and

mounted. The pinions and shafts are in one piece, hardened and polished. The larger shafts run in high grade ball bearings, assuring a minimum and constant friction. With a drop of the driving weights of 80″, the clock will run 2 hours. A set of maintaining gears is provided only when specially requested.

Printing Mechanism and Control. A shaft extending from the driving clock, running at a speed of 1 revolution per second, carries a ratchet wheel with 100 teeth, in which engages a pawl attached to a shaft coaxial with the clock shaft on which is mounted the first (.01 seconds) type wheel. The pawl is disengaged from the ratchet wheel through the operation of the small electro magnet (control magnet) without interfering with the speed of the driving clock. The method of control is as follows:

The clock is adjusted to run sufficiently fast to gain about 1 second in 6 minutes. The control magnet, which is connected through a relay in the chronograph with the regular clock or chronometer, receives by means of a special contact device, an impulse only when the chronograph driving clock has gained .01 seconds; then the pawl is disengaged and the 1/100 seconds type wheel retarded for .01 seconds.

In order to have the control operate with a regulator clock or chronometer which does not make a contact every second, a device is provided which allows an impulse to the control magnet only every fourth second.

The type wheels are independently mounted on coaxial shafts running in ball bearings, and are actuated through the driving clock. The first wheel, for printing hundredths of seconds, has a continuous rotation as given by the pawl engaging in the 100-tooth ratchet wheel on the clock shaft. The wheel has, adjacent to the type, a graduated scale with 200 raised lines, each being equivalent to 0.005 seconds. The next type wheel, for printing seconds, is actuated through a cam attached to the first wheel. The third type wheel, for printing minutes, is also actuated through a cam attached to the second wheel shaft. The exact printing positions of the second and minute wheels are shown on 2 clock dials.

The three printing hammers are attached to stiff springs and mounted on the rotating armature of a strong electro magnet. They strike the paper tape stretched over the type wheels a sharp blow and rebound instantly without any effect on the rotation of the type wheels. The paper feed mechanism consists of 2 rollers actuated through a ratchet wheel, which is operated by an electro magnet. Immediately after printing, the paper is shifted and ready for the next print. The paper is of good white grade, 50 mm by about 50 meters long. The prints are made through a silk ribbon, similar to those used in typewriters, which is shifted automatically after every print.

Relays. The relays, mounted in the case below, are specially designed to give a quick "make" or "break" contact with minimum lag, and are easily accessible through the removable panel. One panel of the case is fitted with a plug to which the supply of 12 volts D. C. is connected. A voltmeter, the main switch, and 3 switches for check, setting, and control, are mounted on the second panel, and the third panel carries 6 terminals, 2 of these for connecting the regulator clock, the second 2 for the printing key, and the last 2 for the spacing key; the last 4 terminals can be connected to contact keys at any desired distance. On top of the bakelite base, above these terminals, 2 contact keys are mounted for direct operation of the printing and spacing. An independent action for spacing is required when an extra wide space is wanted between 2 records.

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ANALYTICAL BALANCES. Bulletin describes the Rueprecht System for quick and accurate weighing. Alb. Rueprecht & Sohn, Favoritenstrasse 25, Vienna, Austria.

APPARATUS INSULATORS. This circular describes Outdoor Apparatus Insulators, which have a broad application for assembling switchgear apparatus, such as bus supports, disconnecting switches, etc. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

AUDIO FREQUENCY TRANSFORMERS. This booklet describes in detail audio frequency transformers and choke coils and other equipment for radio receivers and accessories. Ferranti, Inc., 130 West 42 Street, New York, N. Y.

AMPLIFIERS. The 1930 Year Book gives information on audio frequency transformers and radio products with instructions for building power amplifiers. Ferranti, Inc., 130 West 42 Street, New York, N. Y.

BRIDGE-MEG. Bulletin 1255 describes the Bridge-Meg resistance tester for testing resistance from .01 ohm to 100 megohms. James Biddle, 1211 Arch Street, Philadelphia Pa.

BRISTOL'S RECORDING INSTRUMENTS. Bulletin 362 illustrates recording instruments in the power plant. Bristol Company, Waterbury, Conn.

BUS-BAR SUPPORTS. Circular 1825 supplies information on the Westinghouse Type H bus-bar supports. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

CONTACT CABLE. Leaflet describes a cable which can be pressed at any point and close a circuit, replacing a switch. Bishop Wire & Cable Corp., 420 Lexington Ave., New York, N. Y.

CYCLOMETER. Leaflet covers cyclometers, speedometers and counters. This is printed in English. Bernhard Thormann, Berlin NO 18, Germany.

DUO-STAT. Leaflet describes an instrument for steam, vapor and vacuum heating systems, as well as hot water systems. F. I. Raymond Co., 228 North La Salle St., Chicago, Ill. A bulletin contains instructions for installation and operation of the Duo-State for hot water heating plants.

ELECTRIC OVEN CONTROL. Leaflet illustrates an oven control. Struthers Dunn, inc., 1130 Race Street, Philadelphia, Pa.

FLOW METERS. Bulletin E-3 covers indicating flow meters for gas, air, steam, oil and water. Metric Metal Works, Erie, Pa.

GENERAL RADIO EXPERIMENTER. The October issue of the experimenter contains: A Low Frequency Oscillator and Notes on Power Measurement in Communication Circuits. The November issue contains the following articles: Notes on Power Measurement in Communication Circuits, Part II, and Temperature Control for Piezo-Electric Oscilators. General Radio Company, Cambridge, Mass.

GAS LEAK FINDER. Leaflet illustrates and describes a gas leak indicator. Alpha-Lux Company, Inc., 192 Front Street, New York, N. Y.

GAS SERVICE JOURNAL. The November issue contains the following articles: Gas Meters at the Curb. Success of Water Companies interests Gas Men; Flow of Natural Gas Through High Pressure Transmission Lines; Problems of the Gas Industry. Pittsburgh Equitable Meter Company, 400 Lexington Ave., New York, N. Y.

HYDROGEN ION MEASUREMENT. Bulletin is entitled "Permanent Colorimetric pH Standards for the Control of Industrial Processes." Braun-Knecht-Heimann Company, 876 Mission Street, San Francisco, Calif.

HERBERT PENDULUM AND "CLOUD-BURST" MACHINE. Bulletin No. 4 covers these two instruments for hardness testing and superhardening of metals. Tinius Olsen Testing Machine Company, Philadelphia, Pa.

IT DOESN'T PAY TO BOTHER WITH THE OLD BELL-RINGING MAGNETO. A leaflet on the megohmer for insulation measurements. Herman H. Sticht & Company, 21 Park Row, New York, N. Y.

LEVEL FLIGHT AND ALTITUDE INDICATOR. Leaflet describes the Paulin level flight and altitude indicator. Pioneer Instrument Company, 754 Lexington Ave., Brooklyn, N. Y.

LANTERN. Leaflet covers a lecture lantern permitting the lecturer to face the audience and the lantern. Spencer Lens Company, Buffalo, N. Y.

LABORATORY. Volume Two, No. Five contains the following articles: Thomas Edison-Chemist; Who Invented the Uniformity of Manufacture; A new Illuminator, serves for all Laboratory instruments, etc. Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.

MORE BLAST FURNACE OUTFIT-PER POUND OF COKE. The bulletin covers the applications of instruments to the blast furnace. Brown Instrument Company, 4482 Wayne St., Philadelphia, Pa.

MOTOCO INDUSTRIAL THERMOMETERS. Leaflet illustrates various types of thermometers. Motometer Gauge & Equipment Company, Long Island City, New York.

MASTER PRESSURE GAGES. Circular No. 101-E illustrates the Ashton Master Pressure and Master Pilot Gages. The Ashton Valve Company, 161 First St., Boston, Mass.

MODERN INSTRUMENTS FOR FLOW MEASUREMENTS. This is the title of Bulletin 249, which is a leaflet illustrating the general line of instruments of the Builders Iron Foundry, 9 Codding Street, Providence, R. I.

OUTDOOR SWITCHHOUSES. Circular 1861 covers outdoor switchhouses with manual, motor, or solenoid-operated oil circuit breakers. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

PYRO RAPID RECORDER. Leaflet is an announcement of a new recorder, which will indicate quick temperature changes. Pyrometer Instrument Company, 50 Howard Street, New York, N. Y.

POTENTIOMETERS. Leaflet gives brief descriptions and prices of potentiometers and resistance boxes. Gray Instrument Company, 64 Johnson Street, Philadelphia, Pa.

RECORDING THERMOMETERS. Leaflet describes the new Model 1000 recording thermometer of the Moto Meter Gauge & Equipment Corporation, Long Island City, New York, N. Y.

RADIO PRODUCTS. Leaflet gives list prices, weights and dimensions of Ferranti radio products. Ferranti, Inc., 130 West 42 Street, New York, N. Y.

SOLENOID VALVE. Bulletin S-89 describes in detail the 682 Arco Solenoid Valve for oil, gas, water, air, etc. The Mercoid Corporation, 564 West Adams Street, Chicago, Ill.

SPECIFIC GRAVITY RECORDING GAGE FOR GAS. Leaflet illustrates chart of the recorder. Alpha-Lux Co., Inc., 192 Front Street, New York, N. Y.

THE SPERRYSCOPE. Vol. 6, No. 1, contains the following articles: Making Daylight for the Aviator; Australian Airway Lighted by Sperry Beacons; Whaling Industry uses modern Equipment; Magnificent Lighting Display Features Barcelona Exposition; The Endless Search for Mechanical Perfection, etc. Sperry Gyroscope Company, Inc., Brooklyn, N. Y.

FURNACE DRAFT CONTROL. Bulletin No. 100 covers an automatic draft control for boilers. Shallcross Contrcl Systems Co., Milwaukee, Wis.

WIDE FIELD BINOCULAR MICROSCOPE. Pamphlet No. 1169 describes a new model wide field binocular microscope with automatic multiple objective nosepiece. E. Leitz, Inc., 60 E. 10th St., New York, N. Y.

EOTVOS—RYBAR TORSION BALANCE. Bulletin describes the small Eotvos-Rybar torsion balance for automatic registration. Another bulletin describes the small original Eotvos Torsion Balance. George Steiner, Petroleum Bldg., Houston, Texas.

WATER WORKS JOURNAL. The December 1929 issue of this house organ contains the following: Water Works System of East Chicago and Indiana Harbor, Ind.; The Washington Situation; West Chicago Municipal Water Works. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

TECHNICAL INSTRUMENT BULLETIN. The December issue of this house organ contains the following articles: The Calculation of a Microscope Objective, and The Use of Reflected Light in the Microscopical Examination of Textiles and Papers. Emil Busch Optical Co., Ltd., Diamond House, Hatton Garden, London E. C. 1, England.

PRIMING VALUE TESTER. Booklet describes and gives instruction for use of a new apparatus for determining the ignition of motor fuels, lubricating oils, and other inflammable materials. Another booklet illustrates its applications. These are printed in English. Julius Peters, Berlin, Germany.

STEAM FLOW METERS. Bulletin No. 162 describes Foxboro Flow Meters for steam flow measurement. Foxboro Co., Foxboro, Mass.

COMPLETE X-RAY APPARATUS FOR LABORATORIES. Prospect No. 15 illustrates X-ray apparatus for the laboratory. This is printed in German. Seemann Laboratorium, Freiburg i. Br., Rheinstr, 4, Germany.

X-RAY SPEKTROGRAPH. Prospekt No. 20 illustrates an X-ray spektrograph for emission analysis and a Universal Spektrograph. Seemann Laboratorium, Freiburg i. Br., Rheinstr, 4, Germany.

HEAT FLOW METER. Bulletin 4800 describes the Weston Heat Flow Meter. Other points considered are: Theory of Operation; Examples of Measurements and Accuracy; Corrections for Errors; Temperature Measurements; and Precautions in Using Heat Flow Meter. Weston Electrical Instrument Corp., 591 Frelinghuysen Ave., Newark, N. J.

SCIENTIFIC INSTRUMENTS. Folder containing information on the various instruments manufactured by P. J. Kipp & Zonen. This is printed in English and issued in loose leaf form. P. J. Kipp & Zonen, Delft, Holland.

STEAM DEMAND VS HEADER PRESSURE. Feature No. 10 illustrates by a comparison of charts the relation between steam demand and header pressure. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

TESTING MACHINES. Folder of leaflets and bulletins illustrating the physical testing machines manufactured by Losenhausenwerk, Alfred Suter, 200 Fifth Ave., New York, N. Y.

TOOL YOUR PLANT FOR THOROUGH CONTROL OF TEMPERATURES. This is the title of a direct mail piece giving illustrations of installations as well as a photograph of the enlarged Leeds & Northrup Plant. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

WARM AIR FURNACE CONTROL. Leaflet illustrates a new design in warm air furnace controls employing a thermostatic metal coil. The Mercoid Corporation, 564 West Adams Street, Chicago, Ill.

WATTHOUR METERS. Leaflet 20433 fully describes detachable watthour meters for indoor and outdoor use. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

WESTCOTT VOLUME AND PRESSURE GAGE. Bulletin E-6 covers the measurement of gases and gives pressure and temperature factors for natural and manufactured gas. Metric Metal Works, Erie, Pa.

MADE TO ORDER WEATHER. Leaflet describes the Carrier weathermaker for the home. Carrier-Lyle Corporation, 39 Cortlandt Street, New York, N. Y.

RECORDING PRESSURE AND VACUUM GAUGES. A very complete folder of catalogues on recording pressure and vacuum gauges. A complete list of available charts is also included. Bristol Company, Waterbury, Conn.

INSTRUMENT DATA BOOK FOR STEEL TREATING. This 32 page, well illustrated booklet presents a summary of 23 different heat treating processes where temperature control is important. Each process is briefly described, the heat treatment best suited to the need is outlined, and the furnaces and instruments ordinarily used are indicated. Brown Instrument Company, 4482 Wayne Street, Philadelphia, Pa.

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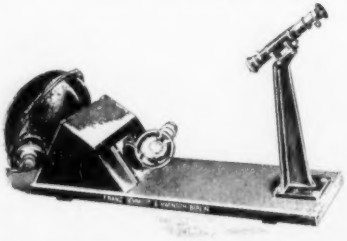

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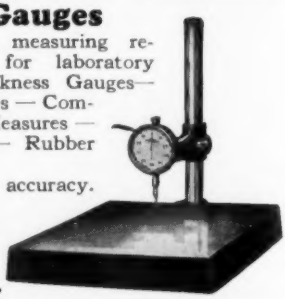

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M. F. BÉHAR, INSTRUMENTS, Vol. 3, No. 1, January 1930, pages 3-13, 8 figs.

A detailed review of the developments made in this field during 1929.

RECENT ADVANCES IN COLORIMETRY

FOSTER DEE SNELL, INSTRUMENTS, Vol. 3, No. 1, January 1930, pages 15-19, 4 figs.

The author covers the advances in colorimetric measurement during the past few years. The instruments of Leitz, Hellige-Klett and Bausch & Lomb are illustrated.

AIRCRAFT INSTRUMENTS

DR. W. G. BROMBACHER, INSTRUMENTS, Vol. 3, No. 1, January 1930, pages 21-30.

Aircraft instruments are separated into 4 groups, (1) for the power plant, (2) for speed, (3) for altitude, and (4) for navigation. General performance requirements are outlined.

Standard dimensions for some of the instruments have been adopted. This makes these instruments interchangeable on the instrument board, and this is considered an outstanding achievement.

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ARTHUR SCHRODER, INSTRUMENTS, Vol. 3, No. 1, January 1930, pages 31-34, 9 figs.

A review of the developments during 1929.

ELETRICAL INSTRUMENTS DEVELOPMENT DURING 1929

E. S. LINCOLN, INSTRUMENTS, Vol. 3, No. 1, January 1930, pages 35-37, 1 fig.

A brief résumé of the 1929 developments of electrical instruments.

THE ENGINEER'S HANDBOOK OF INDUSTRIAL INSTRUMENTS

M. F. BÉHAR, INSTRUMENTS, Vol. 3, No. 1, January 1930, pages 39-49.

This is the first installment of a series of articles on Industrial Instruments. Industrial Instruments are defined. Processing conditions are discussed.

MEASUREMENTS—INDUSTRIAL AND SCIENTIFIC

DR. WALTER BLOCK, INSTRUMENTS, Vol. 3, No. 1, January 1930, pages 51-58, 1 fig.

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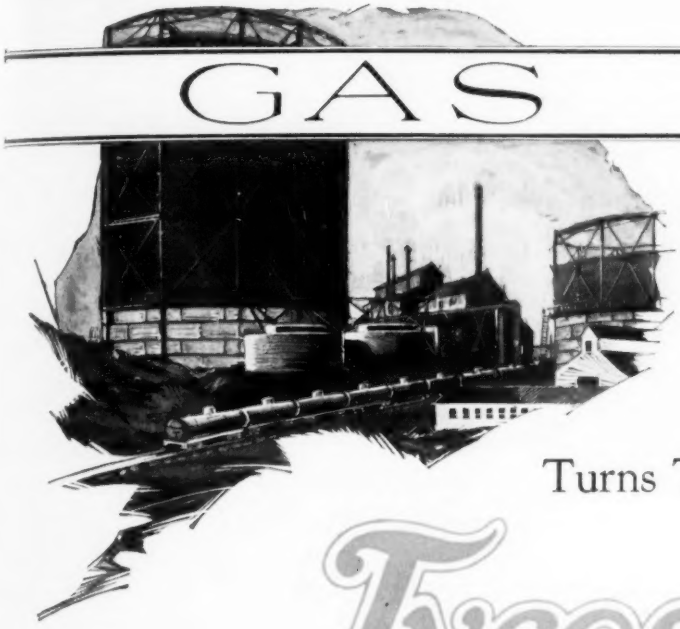

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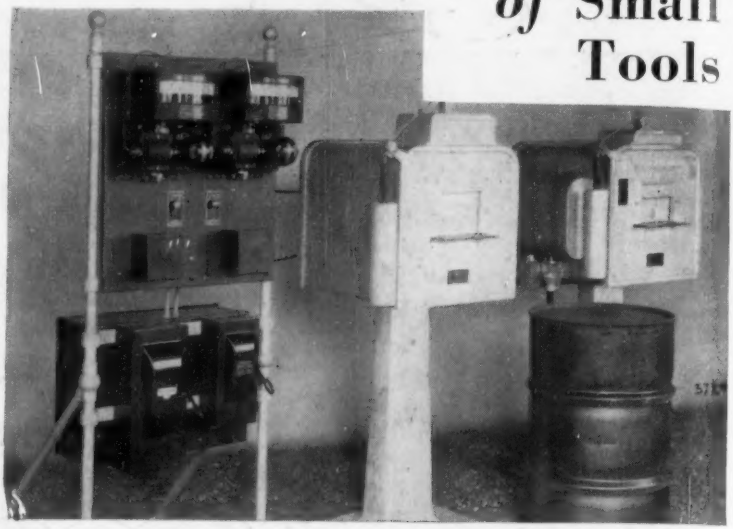

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